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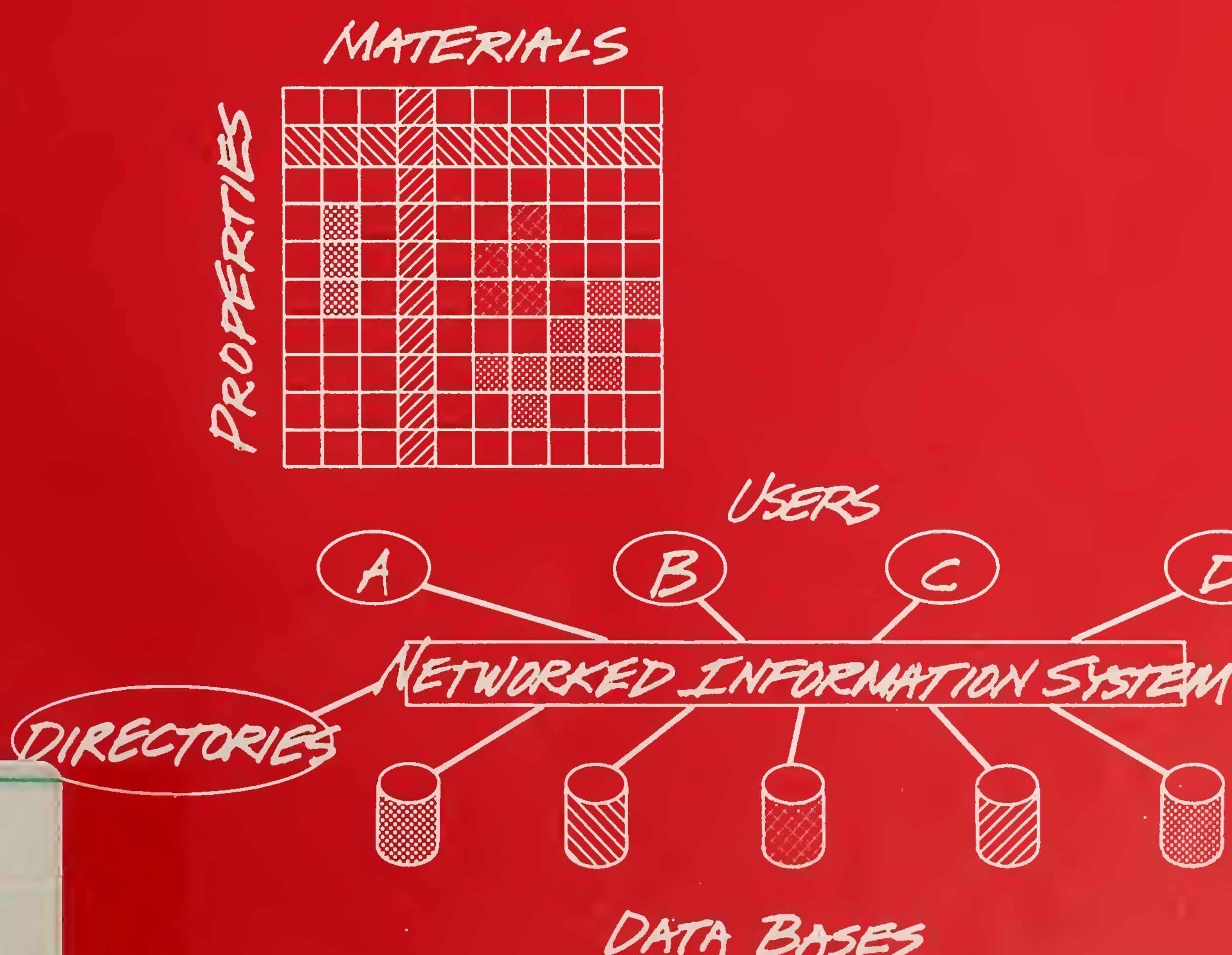
Towards a Tribology Information System

John Rumble, Jr. and Lewis Sibley, Editors



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[2]Some divisions within the center are located at Boulder, CO 80303.
[3]Located at Boulder, CO, with some elements at Gaithersburg, MD

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Towards a Tribology Information System

The Results of a Planning Workshop Held at the National Bureau of Standards, July–August, 1985

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FOREWORD

This report summarizes the findings of a planning workshop at the National Bureau of Standards during July and August 1985. Participants included both tribologists and computer database specialists with the aim of building a Tribology Information System. The idea for the workshop arose from discussions involving the U.S. Department of Energy, the Energy Conservation and Utilization Technology Division, the Research Committee on Tribology of the American Society of Mechanical Engineers, and the Metallurgy Division, the Ceramics Division, and the Standard Reference Data Program of the National Bureau of Standards.

This planning group for the workshop included:

ASME Research Committee on Tribology
Lewis Sibley, Tribology Consultants, Inc.
Marshall Peterson, Wear Sciences Corporation

National Bureau of Standards
A. William Ruff, Metallurgy Division
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John Rumble
Lew Sibley

SUMMARY

A workshop was held in July 1985 to address the needs for a computerized tribology information and data system, as well as possible implementation schemes. The meeting was sponsored by the American Society of Mechanical Engineers, Research Committee on Tribology, the Department of Energy, Energy Conservation and Utilization Technology Division, and the National Bureau of Standards. The views of a broad sector of industry, academia, and government were obtained over a four-week period through participation by about 60 individuals. Specific categories that were treated were design, numeric data, bibliography, research in progress, newsletter, and product directory. The principal discussion content and the recommendations in each subject category are summarized here. There was general agreement that a system of this type would be broadly useful to the engineering community for the purpose of design and materials selection, and for the research community as an important aid in information access and flow.

The workshop recommendations detailed four phases of development, starting with a demonstration prototype system and concluding with a full-scale operating data and information base. Specific plans in each phase and for each subject area were developed and are presented here. While continual input will be sought from the technical community to refine those plans, it is hoped that immediate efforts can begin in at least some of the areas, and that system use will quickly develop to a significant level, both nationally and internationally.

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PART A - A TRIBOLOGY DATA SYSTEM

CHAPTER 1

BACKGROUND AND RECOMMENDATIONS

Tribology, the science and technology of interacting surfaces in relative motion, has evolved from the classical fields of lubrication, friction, and wear. Those are among the oldest technologies involved in mechanical devices, dating back to 3500 B.C. Tribo-elements are components of virtually every mechanical system. The performance of these bearings, clutches, seals, and other elements vitally affects the ability to control motion and critically influences the reliability, life, and energy efficiency of all systems.

Today, mechanical systems are called upon to be better in every respect: they must last longer, be more energy-efficient, and cost less to produce. To meet these demands, engineers have turned to a number of recently developed tools, namely, advanced materials, computers, and new design and manufacturing techniques. While substantial changes have taken place in the last decade, there are many more to come.

In July 1985, a workshop was held to address the impact computerized information systems could have in tribology. Six different types of information that both tribologists and mechanical product designers use in their work were identified and discussed. These were:

- bibliographic
- "factual" data (numbers, graphs, etc.)
- software for design of tribological elements
- research in progress
- product directories
- informal information exchange (electronic mail, newsletters, etc.)

In each of these areas, it was determined that a computerized service which made this information more easily and comprehensively available would be of value to persons involved in tribological work. So convincing was this result that many organizations have already pledged support to bring the highest priority items into existence.

The workshop was built upon the recommendations of an earlier meeting [1] held in January 1985. At that meeting, a broad overview of tribology was presented. One recommendation was that information services for tribology be improved and set up to utilize the power of computers. Because the report from the January meeting covers the field thoroughly, this report will not repeat the background material but rather will limit its focus to the questions and issues related to information services only.

The Research Committee on Tribology of the American Society of Mechanical Engineers and the Energy Conservation and Utilization Technology Division of the Department of Energy acted upon the recommendation noted above. The National Bureau of Standards was asked to organize a wide representation of tribologists, information scientists, and database experts. The organization and makeup of the workshop are described more completely in Appendix A.

The following summarizes the recommendations of the workshop and the reports from six working groups. The appendices include a detailed work plan for the first two phases of the recommendation.

Recommendations

Two primary information services are recommended to meet the needs of the two communities for tribological information. For the general mechanical design community, a factual database of properties of lubricants and characteristics of tribological components will be developed by experts. Only the "best" values as designated by experts in the fields will be included.

For tribological designers and researchers, a comprehensive information service focused on computer design models as well as access to the research literature on tribology is needed. (See Table 1-1.)

The workshop also recommended the following four-phase plan:

Phase	Major Goal
I	Demonstration of design codes
II	Prototype system of factual data and design codes
III	Operational system of factual data and design codes
IV	Complete comprehensive tribology information system

Each phase of Table 1-1 represents a major difference in level of funding, goals, and commitment by the tribology community. Phase I is intended to be strictly a demonstration project, resulting in a small package of design codes and access capabilities that could be demonstrated at trade shows and other meetings.

The second phase requires a greater commitment. The results of this phase will be a prototype tribology data system that could be used as a working tool by part of the tribology community. It will contain factual data in several areas of tribology as well as several design codes available in a uniform way. It is possible that the total work effort could be separated at this point as resources and interests demand. The user community would be drawn from the area covered.

The third phase of the system would see the completion of a comprehensive operational system that would have appeal to the broad community, though full implementation would only be aimed at a few areas. At the end of this phase, a self-supporting system would be achieved.

The fourth and final stage would result in a full information system that would in essence provide complete access to the information that tribologists need to support their work. It would also include some expert system capability to allow for better design and selection of tribological components.

Table 1-1

Plans for a Tribology Information System

	Phase 1	Phase 2	Phase 3	Phase 4
System Capabilities	Vax environment at OSTI Access Telenet	Vax environment at OSTI with a Gateway to remote bibliographic systems	30 simultaneous users	A natural language interface
Design Codes	Two FORTRAN codes with common access	12 design codes	Prototype expert system	Comprehensive expert systems
Bibliographic Databases	Access to two existing on-line databases	Additional databases, comprehensive thesaurus for tribology	Common search thesaurus and search language	Natural language interface, full text searching, standards and codes
Numeric Databases				
For Design Codes	Data to support each design code	Data to support design codes	Linkage to full numeric database	Same as Phase 3
Evaluated Tribology Data	No work	10 databases built in areas of tribology	Databases from handbooks	All numeric data of interest
Research in Progress	Access to OSTI RIP database	Government tribology research	Summaries of all tribology research	Same as Phase 3
Newsletter	Electronic mail for user feedback	Same as Phase 1	Same as Phase 1	Bulletin board, calendar, and conferencing capabilities
Product Directory	No work	Request for information from consultants	Limited database of catalogs and consultants	Catalog and consultants database expanded

CHAPTER 2

PHASE 1 - A DEMONSTRATION SYSTEM

As with any complex information system, a prototype model is worth its weight in gold. Consequently, it was decided that a demonstration version of a tribology design data system would be developed and used for the following:

- to demonstrate at technical meetings and workshops
- to aid in fundraising
- to sharpen the ideas for later versions
- to involve important players immediately

To this end, a great deal of effort went into defining a set of capabilities that would allow for achieving the above goals yet could be accomplished in a reasonable time. Further, wherever possible, the demonstration would build upon existing capabilities.

The resulting demonstration project summarized in Table 2-1 is intended to show a system that makes available several design codes, provides access to representative bibliographic and research-in-progress databases, and has an electronic mail function. The demonstration will be implemented on an IBM PC computer that has access through modems via a commercial communications network to outside computers. The design codes would be available for demonstration purposes only.

A maximum of five tribology design codes would be put up along with a small amount of numerical data on materials and lubricants properties. There would be no attempt to make the codes uniform, but the user would choose among the codes and would be responsible for knowing how to execute each code.

The selection of the codes would be the responsibility of the project manager, who also will have to make all arrangements for their use. The menu development and computer work will be done at Los Alamos National Laboratory.

Access to bibliographic databases would center on the DOE Energy database, Base Tribo, and Metadex, available on the Chemical Abstract Service network. This would be provided as an automatic dial-up and log-on capability through the DOE Office of Scientific and Technical Information (OSTI) and included as an option on the menu interface discussed above. A value-added network will be used for communications.

In addition, the same communications linkages would be employed to provide access to the DOE Research in Progress database maintained at OSTI and an electronic mail capability on the OSTI VAX. system.

The resulting demonstration package should be interesting enough to whet the appetites of the potential user community. The work itself will be done in such a way as to be extendable to later stages, as discussed in the following chapters.

Table 2-1

Phase 1 - A Demonstration System

System Capabilities	Design Codes	Bibliographic Databases
Vax environment at OSTI. Access through Arpanet and Telenet	Five codes written in FORTRAN, accessible through a common menu screen. Codes <u>not</u> necessarily compatible with respect to variable names, input formats, or output display	Automatic dial-up to two existing on-line databases
Numeric Databases for Design Codes	**Numeric Databases of Evaluated Tribology Data**	**Product Directory**
Small databases with data on materials properties and lubricants needed to support each individual design code as provided by the code builders	No work in this phase	No work in this phase
Newsletter	**Research in Progress**	
Electronic mail as an opportunity to provide user feedback	Automatic dial-up to OSTI Research-in-Progress Database	

CHAPTER 3

PHASE 2 - A PROTOTYPE SYSTEM

The second phase of the database effort is aimed at building a prototype system that can be used by a small number of tribologists. From this use, experience can be obtained that will be important in guiding further developments of a larger information system.

Three parallel efforts are involved, concerned with factual or numerical databases, design codes, and supporting information. While there is some interdependence, the three efforts are sufficiently separate that each may progress based on funding and manpower available. The plan is summarized in Table 3-1.

While a major emphasis at the workshop was on providing better access to design codes, the need was to increase the availability of numeric data to support mechanical designs. Since the workshop, several groups, including government funding agencies, have highlighted the numeric database effort as being of highest priority to support their missions. The result has been to develop detailed plans to evaluate data and build databases in 10 important areas.

As indicated earlier, the plans for Phases II-IV are modular in nature and thus the separate parts are more relatively independent of one another.

The first numeric database effort is proposed to support data evaluation work. The emphasis will be to aid experts who are collecting and evaluating data in several areas of tribology, but dissemination of these databases to the user community will not be done in this phase. For each area, a database designer will work with the evaluator to set up a data entry system making use of the convenience and flexibility of personal computers. Using a PC database management system such as dBase III, data entry screens will be designed and simple report generation and data manipulation added. Though it is desirable to have as much uniformity as possible between the terminology and formats for the same variables across databases, commonly called a consistent data dictionary, the need to set up procedures for up to 10 groups within a short time span may preclude this.

Ten data areas have been identified (see Epilogue Figure E-3) that are considered to be of high priority and related to one another. These were selected by the government steering committee from the broader list established by a technical advisory committee of experts (Table 3-2).

The design code effort is intended to provide consistent easy access to a number of standard software packages presently in use for tribological design. A major attempt will be made to ensure that the input variables have been made uniform with respect to their names, units, and formats. If feasible, a standard input format will be set up so that files of various input parameters could be used for more than one software package. The output formats would similarly be made uniform and consistent so that results for equivalent design situations are presented in a comparable way, though generated by more than one code. The number of codes will increase up to 12 as quality, funding, and time permit.

Table 3-1

Phase 2 — A Prototype System

System Capabilities	Design Codes	Bibliographic Databases
Vax environment at OSTI with a gateway to remote bibliographic systems (see below). This will provide database linkage and data transfer. Users will have access to tutorials on the use of the system as well as be able to download data	The number of design codes will increase to 12. Consistent access will be possible with uniformity of variable names, consistent input formats, and compatible outputs. Expert system interface work would begin	Access will be provided to additional databases. First will be BAM abstracts, followed by others such as Compendex and Canadian sources. Work will begin on a comprehensive thesaurus for tribology
Numeric Databases for Design Codes	**Numeric Databases of Evaluated Tribology Data**	**Product Directory**
Two databases will be made in support of design codes, one for lubricants and one for materials property data. These databases will be made by combining data supplied the code builders	Ten databases will be built in various areas of tribology (see text for list). These will reside on personal computers	Begin building a consultants directory by issuing a request for information. Also, plans will be set for a survey of vendors and the need for an on-line directory
Newsletter	**Research in Progress**	
Electronic mail as an opportunity to provide user feedback	A database of current tribology research supported by government. Built with support of DOE and NSF	

Table 3-2

Government Steering Committee

Steve Hsu	NBS
Said Jahanmir	NSF
Terry Levinson	DOE
Bobby McConnell	USAF
John Rumble	NBS

Technical Advisory Committee

Prof. E. Klaus, Penn State University, Chairman
Prof. F. Ling, RPI
Prof. H. Cheng, Northwestern University
Prof. D. Dowson, Univ. of Leeds
Prof. H. Czichos, BAM
Mr. M. Peterson, Wear Sciences

An important aspect of this work will be the start of an expert system interface to the design codes. The system is intended to provide a computerized guide to the selection and application of the various design codes. The effort will be on the order of a 1000 rule system, which should provide a significant range of choices and expertise.

Two types of numeric databases will be developed: the first in support of the design codes, the second to collect and manage evaluated tribology data. In support of the design codes, the databases required to operate the codes will be provided primarily by the code writers both for material property and lubricant data.

Because the codes will have uniform input, every effort will be made to create the ability for the database to be linked directly to the code execution. This will allow for the least redundancy and greatest efficiency. The amount of data is not expected to be large, and most likely the user community will want to add to it. Therefore, a capability for adding and updating these databases in a controlled way will be made available.

Consistency with the above-mentioned databases for support of the design codes is even more desirable, since then the evaluation work can be more easily interfaced with the codes themselves; however, the constraints again make this problematic at this phase. A further complication is that the tribology community itself has not yet established a definitive terminology.

As the workshop clearly brought out, the tribology community has a strong need for information other than numeric data and design results. This is in the form of bibliographic references, summaries of ongoing research, and

access to product and people information. The demonstration phase of this program will have resulted in simple access to some of these, but a more concerted effort is planned under this phase.

New bibliographic sources may be added to the system. For example, a recent compilation of Canadian literature sources will be added. Also, the extensive and well-regarded bibliographic services of the BAM will be accessible by a direct transfer. Arrangements for this work will be made by OSTI and BAM.

To facilitate the use of the bibliographies, a general description of each database will be developed and made accessible as a user aid. In addition, work will begin on developing a comprehensive and consistent thesaurus so that literature-searching can be done with more precision.

The research-in-progress database will be improved by the addition of descriptions of work now funded by the government, resulting from a present DOE project. A similar survey for private sector research will be initiated.

Finally, two efforts will be mounted to make the information products and people related to tribology work more easily available. A directory of tribology consultants has been proposed. Also, work will be done to determine the feasibility of including information on directories of vendor information. The prognosis for future offerings in this area will be made.

As was mentioned above, the work outlined falls into separate categories that can be funded and staffed independently of other work. Several government agencies have already indicated their interest and willingness to support particular efforts. The American Society of Mechanical Engineers, through its Research Committee on Tribology, has expressed its desire to concentrate on the design code efforts. Industry would be involved through fund-raising efforts headed by ASME. The Department of Energy, through its Conservation Division, and OSTI are interested in the bibliographic and research-in-progress efforts. Finally, the National Science Foundation, the Department of Defense, and DOE, working with NBS, are interested in supporting the numeric database effort.

Each of the three efforts is designed to take about 12 to 18 months and, when completed, would allow a significant number of users to access the various components. The capabilities would be minimal and would in fact be only a prototype. The numeric databases would not yet be available and the design codes would only have a simple menu interface. The bibliographic and related databases would be more advanced since they would be built on other efforts of DOE OSTI.

At the end of this phase, the tribology community would have a good idea of the power and appeal of a more complete information system, and industry then should be in a position to provide sufficient funding to carry development further, as outlined in the next two chapters.

CHAPTER 4

PHASE 3 - AN OPERATIONAL SYSTEM

The previous effort will result in the basis for an operational tribology information system and will have a projected user group on the order of 10 to 50 people. The next phase of the overall project is intended to make the system as friendly and complete as possible within a two-year period and with an investment of several millions of dollars.

The primary task is to add new information sources and types and to provide a more intelligent interface to the system. The system itself would have numerous capabilities (Table 4-1) as before, with the feedback being provided by the user community.

The bibliographic module would be improved so that multiple databases could be searched simultaneously. This will use tools developed by groups such as OSTI for other applications and will be easily adaptable to tribology. Work would be done to abstract and load into a separate database tribology literature from the pre-1950 era which is now incompletely covered.

The greatest change would be in the availability of new search tools, in particular, a common thesaurus and search language. Because the terminology in tribology is presently ill-defined, the development of the thesaurus will represent a great improvement in accessing the literature.

The design codes would also show a significant gain, with the major development being an expert system of about 1000-1500 rules for component selection. This system would be aimed at directing users to the most appropriate design code(s) for a particular application. When this expert system is added to the already existing consistent set of codes, the design module would become a powerful tool to improve the quality of tribological design.

Improvements would also be made to the numerical databases to support the design codes as well as to those for lubricant selection and component selection. The first addition will be the provision of an easily accessible numerical database resulting from the evaluation work of the previous phase. Database access may be in conjunction with groups such as the National Materials Property Data Network. It may take the form of diskettes for personal computers and/or larger databases on a network system. The advantage to this would be that, through the collective and cooperative efforts as coordinated by the MPD Network, tribologists would have access to a far wider range of data than would be possible for this project to provide on its own.

During the third phase, the evaluation effort described earlier would be completed for the first 10 areas selected, and new coverage in new areas would begin.

The research-in-progress database would be enhanced to cover tribology research abroad as well as in the U.S.

Table 4-1

Phase 3 - An Operational System

System Capabilities	Design Codes	Bibliographic Databases
A gateway to remote bibliographic systems providing database linkage and data transfer. There will be tutorials and downloading capability. System will be able to have 30 simultaneous users	12 or more design codes with consistent access. Prototype expert system for component selection with 1000-1500 rules for one particular design area	Capabilities for multiple databases will include common search thesaurus common search language database descriptions index to pre-1970 literature
Numeric Databases for Design Codes	**Numeric Databases of Evaluated Tribology Data**	**Product Directory**
Access in a consistent manner to databases on materials properties and lubricant and additive properties supported	In addition 10 expert databases in various areas, databases from printed sources such as handbooks will be made. Also 4000 articles have data extracted. Initial emphasis will be on roller elements and journal bearings	If feasible, a product directory database of catalogs and consultants will be available. Areas of initial coverage will be disposal of materials, lubricants and coatings for industrial roller bearings

Newsletter	Research in Progress
Electronic mail as an opportunity to provide user feedback	Access to summaries of tribology research, both private and government

The development of more comprehensive access to product directories in computerized form will depend on the results of the studies done in the earlier work. If the economics and feasibility look promising, then it is envisioned that two types of product directories would be developed.

Catalogs and consultants that would cover the following:

- disposable materials
- lubricants
- coatings
- a typical component industrial roller bearing

The system would have the same electronic mail capability as before.

At the end of the third stage, the system would be in an operational state and the user community could then be enlarged to include the tribology public at large. This would mean that decisions would have to be made about who would operate, maintain, and update the system, and provide training and support for those users. It has been noted that about 25-30 percent of the total costs of the system is needed for the last activity.

Several possibilities exist for accomplishing these matters, including the MPD Network, ASME, or some other information vendor. There is a lot to be said for choosing one that deals primarily with the technical community so that they have experience with the particulars of that market place.

By this stage, one could also say that a real tribology information system exists and that further developments then rest upon its acceptance and use by the tribology community.

CHAPTER 5

PHASE 4 - THE IDEAL SYSTEM

Even though at the end of the third phase, the information system would be fully operational and available to the public, the workshop thought it was desirable to project into the future about what the ideal system would look like. The main components can be defined as:

- an easy-to-use system that requires little training
- the full realm of tribological data, all well documented and evaluated
- expert systems to guide in the design and selection of tribological components

Table 5-1 summarizes the key features of such a system.

The system itself as seen by the user would have a natural language interface--that is, the user could pose questions in the form of sentences, a capability that is being developed by computer scientists for use in many areas during the next few years. The system would also have a distributed database capability that would allow the user to access desired databases in a consistent and transparent way regardless of location. Again, this would draw on technology that is being developed for many application areas.

With respect to bibliographic sources, the access to these databases would also feature a natural language interface. Here the user is able to pose search strategy in normal sentences. Full text of data sources would be made available if they existed, and access would be provided to all the standards and codes relevant to tribology.

A research-in-progress database would cover efforts both public and private for the U.S. and internationally. It would be updated in a more routine fashion than is now the case, and thus be more timely.

A major enhancement for the ideal system would be with respect to the design codes and how the user would access them. The workshop projected the development of a series of expert systems such that several tribological concerns could be addressed. These would include failure analysis, component selection, analysis of performance, and mathematical modeling.

The development of such expert systems is clearly a large undertaking. The result in terms of better engineering for tribology would eventually pay for the initial investment, but the source of that investment is not clear.

In the area of numerical data, the extension of evaluation activities to the broadest interests of tribology would be done. This would be a program that would have a long-term yield, but again the initial costs would be a problem. However, it is clear that computers have made it tractable to consider generating data from well-controlled experiments and then developing models to extend these data to wider ranges of applicability.

Table 5-1

Phase 4 - An Ideal System

System Capabilities

A gateway to remote bibliographic systems providing database linkage and data transfer. There will be tutorials and downloading capability. System will be able to have 30 simultaneous users. A natural language interface will be added

Design Codes

12 or more design codes with consistent access. More comprehensive expert systems will be added that address many design concerns including choice of mathematical models, analysis of of performance, failure analysis, and component selection

Bibliographic Databases

Capabilities for multiple databases will include:

- natural language interface
- common search thesaurus
- parallel searching of databases
- index to pre-1970 literature
- access to full text searching
- access to standards and codes

Numeric Databases for Design Codes

Access in a consistent manner to databases on materials properties and lubricant and additive properties supported

Numeric Databases of Evaluated Tribology Data

Easy access to all numeric data of interest to tribologists including tribological performance, materials properties, lubricant and additive properties.
Sources will include standard lab tests, field data, research data, and handbook data

Product Directory

Catalog and consultants databases will be expanded to all areas of tribology

Newsletter

Electronic mail as an opportunity to provide user feedback. In addition, system will have a tribology bulletin board, calendar, and conferencing capabilities

Research in Progress

Access to summaries of tribology research, both private and government

In terms of the data content, the ideal system would include tribology performance data from standard laboratory tests and field tests, as well as from research data. The methods for collection and evaluation of field data need to be worked out, but there are models in other areas which can guide developments.

Two other components of the ideal information system deserve mention. The news facility of such a system should include services such as bulletin boards, conferencing, meeting calendars, as well as mail itself. These capabilities clearly exist now but are not in any way combined and available to the tribology community.

Finally, the concept of a complete computerized catalog and product directory was described as being of great appeal to the community. Clearly, the ultimate possibility includes the use of video discs or other image storage devices with the display of pictorial as well as textual information, similar to present-day catalogs. The day when this will be possible is rapidly approaching.

Though the ideal information system as described above is still far into the future, even today almost every part of it has been implemented in one way or another. Two driving forces are at work: first, it is easier and cheaper to do these things each succeeding year; and second, the positive impact such a system would have on American industry is becoming more obvious.

Surely it can be said that the workshop was looking into the future. But we also felt that the future is closer than we anticipate.

PART B - THE TRIBOLOGY DATA WORKSHOP

CHAPTER 6

WORKSHOP GOALS AND DESCRIPTION

As pointed out in the first chapter, the purpose of the workshop was to explore the feasibility of building and operating a computer-based information system to aid in the design and selection of tribology components and activities related to other aspects of tribology. During the organizing meetings for the workshop, it became apparent that such an information system would consist of the six components already mentioned:

- design codes
- numeric databases
- bibliographic databases
- research-in-progress information
- newsletter
- electronic product directory

Accordingly, it was decided that the workshop would consist of a set of small working groups that would develop detailed plans about the exact contents of these components, the tasks necessary to complete the proposed work, and schedules and priorities. These working groups were made up of tribology experts as well as database and system designers.

At the end of the workshop, a committee made up of the chairman of each working group, representative computer specialists, and representatives of various agencies interested in funding the work developed a consensus as to the actual recommendations for each of the proposed four stages of the information system.

As the workshop began, two primary driving forces for a tribology information system became apparent:

(1) the need to design and analyze the performance of various tribological components such as bearings, gears, seals, etc.

(2) the need to provide for the selection of appropriate components by people designing and building mechanical products

This is not to say that there is a clear division between the two activities, but rather that two audiences allow for the setting of priorities and for approaching various groups that are possible sources of funding the overall work.

Unlike other materials data workshops, this particular workshop lasted several weeks with a minimum of overlap between the working groups to permit maximum interactions. The list of participants is given in Appendix A, and the agenda is given in Appendix B.

Prior to the working group meetings, a one-day symposium was held to review other materials data activities and to provide a forum for an overview from

the perspective of the tribology community. Over 50 representatives of U.S. industry, technical societies, and government agencies attended. The agenda for this symposium is also given in Appendix B.

In the next seven chapters, the summary reports of the individual working groups are given. Notice that two separate groups on numeric databases met--one for solid tribological materials and the other on lubricants.

Following these chapters, three chapters contain more detailed plans for the computer aspects of the tribology information system, including fairly detailed schedules and task outlines.

It must be recognized that as with any dynamic activity, the plans, schedules, priorities, and tasks given in this report are indicative rather than definitive. To accomplish the recommendations as given requires numerous resources, both of manpower and finances. The groups that provide the resources, of course, will finally determine what is done and when.

But the overall framework is solid and well-thought-out, and stands as a fine accomplishment of the workshop participants. The combination of tribologists working closely with computer experts resulted in even the most elementary assumptions by each group being challenged and closely examined.

The tribology information system started by these efforts will prove to be a valuable tool for American industry for many years.

CHAPTER 7

DESIGN CODES DATABASE

Group Members: Lewis Sibley, Chairman
William Anderson
Herbert Cheng
Bernard Hamrock
Christie Michelsen
Coda Pan
Donald Shafer
Tibor Tallian
Robert Tucker
Donald Wilcock

Introduction

The market pressures on design engineers to improve the energy efficiency and productivity of machines have increased substantially in recent years. For this reason, machine designers are actively seeking the latest available information on advanced materials and design methods developments to improve their products.

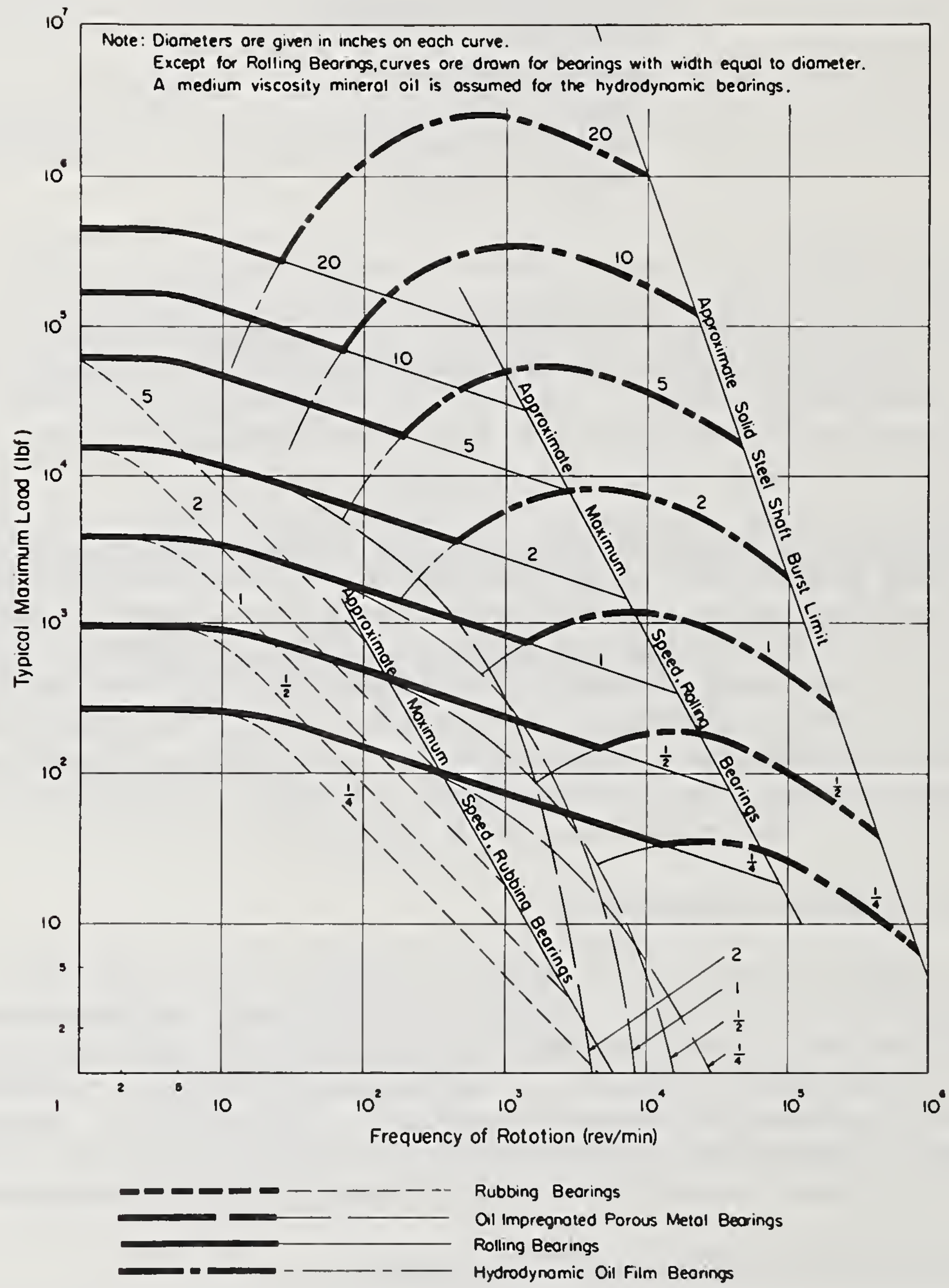
There is a reservoir of advanced computerized design analysis codes available that is not being effectively used by designers. The reason for this is that these specialized design codes often are not readily accessible nor in a form that can be understood and used by design engineers. What is needed is an easily accessible interface between the designer and well evaluated databases that show how the latest materials developments affect the design and performance of machine components. The purpose of the design methods group was to define the orderly step-by-step development of such a service for tribological components such as bearings, gears, seals, etc.

Overall Design Database Development

The eventual primary users of a design database are identified as design engineers responsible for the design, performance, maintenance, failure analysis, and life cycle costs of machinery used in the broad range of industry. A more comprehensive system is envisioned than that required for the straightforward component replacement market. There will be aspects of the service of use to experienced tribologists, but the main aim of the system must be for the broader design engineering community at a reasonable price.

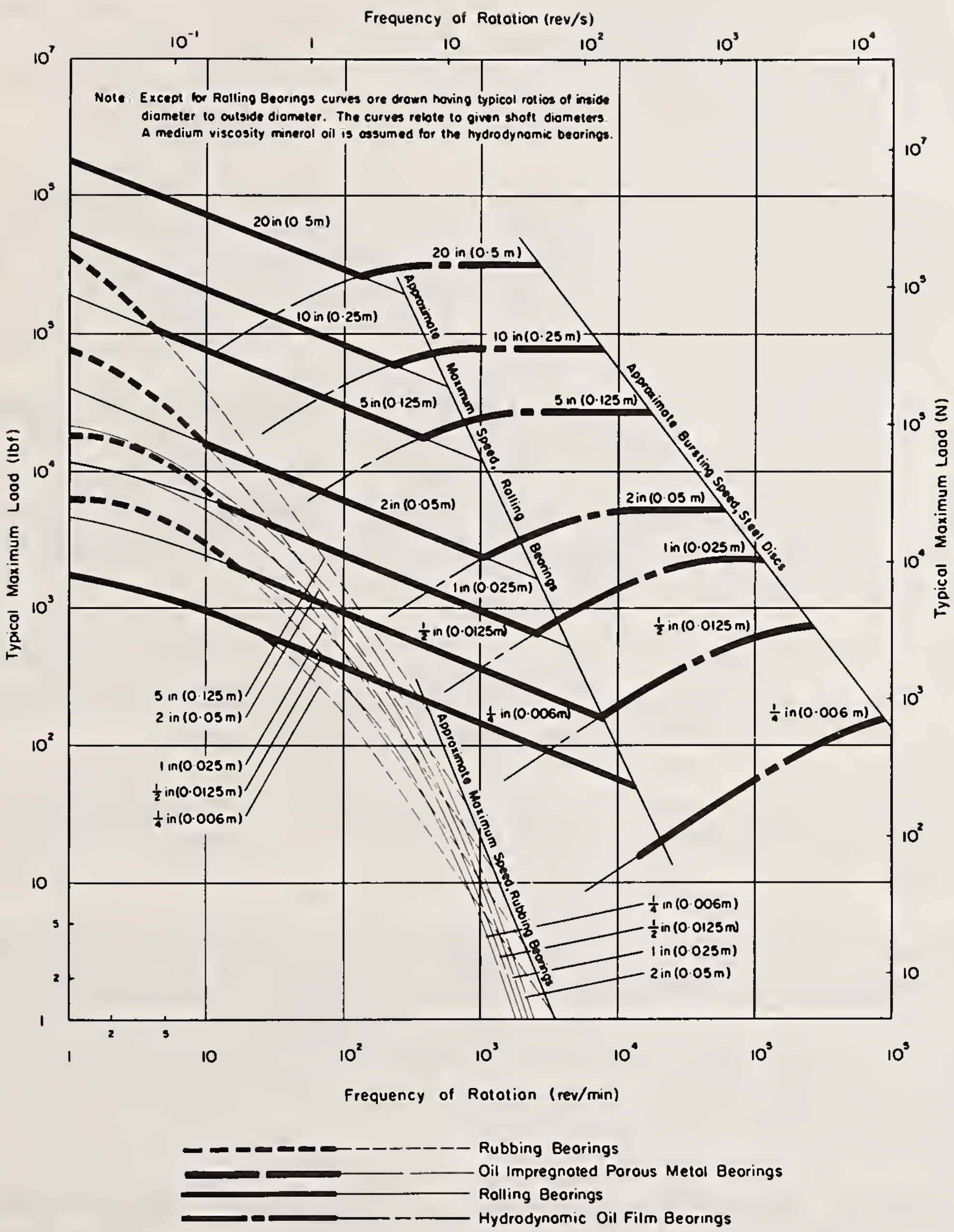
Design Code Selection for Demonstration System

The Computer Support Task Report (Chapter 15) gives proposed menus and logic diagrams for the demonstration prototype system showing what the user will see on the terminal when the service is called up and how the various parts will be tied together into a coherent system. For the design methods section in the demonstration stage, the menu consists of a front-end selection advisor based on the general guide developed by the Engineering Sciences Data Unit (ESDU), as given in Figures 7-1 and 7-2, which is intended to help the user decide what type of component is suitable for the application under consideration. This guide is followed by a selected example of five typical types of component design codes: hydrodynamic oil film bearings, rolling bearings, gas-lubricated bearings, gears, and seals.



General guide to journal bearing type
(From Engineering Sciences Data Unit)

Figure 7-1



General guide to thrust bearing type
(From Engineering Sciences Data Unit)

Figure 7-2

Component design codes that are already available and that have known operating characteristics have been selected for use in the demonstration prototype system, as described below. No primary programming of design codes will be needed through the prototype phase. Wherever possible, codes in the public domain have been selected, although methods for the handling and security of proprietary codes are available if needed. For each code selected, an individual tribologist has been designated who has intimate familiarity with the code and its use for working closely with the system developers to incorporate the code into the system, and then later for working with users in modifying the system to make it most effective and useful.

An important consideration to be addressed is the interface of this tribology system with general and other mechanical design codes. Since there are important interactions of tribological components with other machine elements, the definition of these interactions is a key part of the system that will need to be coordinated with the rest of the mechanical design community.

The following specific component design codes are typical of those considered for incorporation into the demonstration prototype system:

JBMTI, a hydrodynamic oil film journal bearing code from Mechanical Technology, Inc. (cognizant tribologist: Donald Wilcock, Tribolock, Inc.)

EHDSTAR, a ball bearing design code including partial EHD oil film starvation from Tribology Consultants, Inc. (cognizant tribologist: Lewis Sibley, TCI)

HIPRESSA, an externally pressurized air-lubricated journal bearing code from Columbia University (cognizant tribologist: Coda Pan of Columbia)

TELSGEA, a spur gear analysis code from Northwestern University (cognizant tribologist: Herbert Cheng of Northwestern)

SEALS, a mechanical face seal analysis code from Gordon S. Buck, P.E. (cognizant tribologist: Bernard Hamrock, Ohio State University).

Design code catalog sheets for computer interfacing of each of these selected demonstration system codes are given in Appendix C, together with brief descriptions of JBMTI and EHDSTAR. Descriptions of the other three codes are also given in this appendix. It is planned that each design code will be standardized to conform to a single screen input and output, respectively, such as those given in Figure 7-3 for EHDSTAR. Numeric databases will be built into the system to enter the geometric characteristics of each component as a default in response to the input type designated, such as the internal dimensions of the 7007 angular contact ball bearing given in Figure 7-3. In the same way, the properties of the bearing material and lubricating oil will be supplied to the system user in response to input AISI and SAE number designations, respectively, or their equivalents. Of course, both special bearing geometries and special bearing material and lubricant properties can be entered to override the default values.

```
        Sample Input & Output Screens for Design Code EHDSTAR
=====================================================================
                     Copyright 1986 Tribology Consultants, Inc.
SAMPLE INPUT DATA:

      TCI                BALL BEARING DESIGN PROGRAM

        BEARING SIZE & TYPE                    LUBRICANT TEMPERATURE & TYPE
7007       = SERIES & BORE SIZE        120         = BEARING OPER TEMP (F)
        INPUT GEOMETRY                 30          = SAE OIL DESIGNATION
15/.3125  = NO./DIAM OF BALLS (IN)             LUBRICANT CONDITIONS
1.909      = PITCH DIAMETER (IN)       67.7        = VISCOSITY (CS)
15         = CONTACT ANGLE (DEG)       .87         = SPECIFIC GRAVITY
5.6E-06    = COMPOSITE ROUGHNESS (IN)  1.43E-04    = PRESS VISC INDEX (IN2/LB)
.52        = INNER RING CONFORMITY     2.6E-04     = AIR/OIL SURF TENS (LB/IN)
.53        = OUTER RING CONFORMITY             OPERATING CONDITIONS
        MATERIAL TYPE                  9000        = SPEED (RPM)
52100      = BALL MATERIAL DESIGNATION  2          = RADIAL LOAD (LB)
52100/52100 = IR/OR MATERIAL DESIGNATION 40        = THRUST LOAD (LB)
        MATERIAL PROPERTIES            1           = BALL MATERIAL LIFE FACTOR
3.0E+07    = BALL YOUNGS MODULUS (LB/IN2) 1        = IR MATERIAL LIFE FACTOR
3.0E+07    = IR YOUNGS MODULUS (LB/IN2)  1         = OR MATERIAL LIFE FACTOR
3.0E+07    = OR YOUNGS MODULUS (LB/IN2)        CONTROL FLAGS
.30        = BALL POISSONS RATIO       B:7007.TAB = FILENAME TO SAVE
.30        = IR POISSONS RATIO         YES         = ASSUME THRUST LOAD ONLY
.30        = OR POISSONS RATIO         YES         = FIND FILM THICKNESS
.281       = BALL DENSITY (LB/IN3)     YES         = FIND LIFE

F1 = EXECUTE    F2 = FILE LOAD    F3 = QUIT    F4 = FILE SAVE    F5 = FILE OUT

=================================================================================

SAMPLE OUTPUT DATA:

7007 ANGULAR CONTACT BALL BEARING (FILE B:7007.TAB)

15 BALLS    DIAM = .3125 IN    PITCH DIAM = 1.909 IN    CONTACT ANGLE = 15 DEG
IR CONFORMITY = .52    OR CONFORMITY = .53    COMPOSITE ROUGHNESS = 5.6E-06 IN
BALL MATERIAL = 52100    YOUNGS MOD = 3.0E+07 LB/IN2    POISSONS RATIO = .30
IR MATERIAL = 52100      YOUNGS MOD = 3.0E+07 LB/IN2    POISSONS RATIO = .30
OR MATERIAL = 52100      YOUNGS MOD = 3.0E+07 LB/IN2    POISSONS RATIO = .30
BALL DENSITY = .281 LB/IN3   LIFE FACTOR FOR BALL = 1   FOR IR = 1   FOR OR = 1
LUBRICATING OIL SAE NO. = 30    SPECIFIC GRAVITY = .868    TEMPERATURE = 120 F
VISCOSITY (CS) @ 100 F = 1.19E+02    @ 210 F = 1.20E+01    @ 120 F = 6.77E+01
PRESSURE VISCOSITY (IN2/LB) = 1.43E-04    SURFACE TENSION (LB/IN) = 2.6E-04
THRUST LOAD = 40 LB    RADIAL LOAD = 2 LB    SHAFT SPEED = 9.000E+03 RPM

THRUST LOAD ONLY DATA FOR:                          OUTER RING     INNER RING
NORMAL CONTACT FORCE (LB)                              10.2           8.5
CONTACT ANGLE (DEG)                                    15.1           18.3
ROLLING VELOCITY (FT/SEC)                              36.7           36.6
MAXIMUM CONTACT PRESSURE (LB/IN2)                      1.215E+05      1.222E+05
SEMI MAJOR CONTACT AXIS (IN)                           1.531E-02      1.736E-02
AXIS RATIO OF CONTACT ELLIPSE                          5.8            9.0
EHD SPECIFIC OIL FILM THICKNESS RATIO                  .55            .48
OIL MENISCUS DISTANCE FROM CONTACT (IN)                7.20E-04       5.75E-04
OIL STARVATION FILM REDUCTION RATIO                    .06            .06
MATERIAL FATIGUE LIFE (HRS) = 3.60E+05 FOR BEARING     1.09E+06       4.91E+05
```

Figure 7-3

The available documentation for each design code will be incorporated into HELP screens called up to assist the user in defining the input data and in interpreting the output results, when needed. In this way the user can become acquainted with the codes during initial use to any desired depth and avoid lengthy tutorials after familiarization with the code. In addition, depending on the range of parameter values obtained in any particular run, the system will flag special interpretive texts on the screen to advise the user of any unusual component performance characteristics to be expected under the conditions analyzed in that run.

Prototype System Development

More comprehensive available design codes will be added to the system later during the prototype development stage, such as the multiple bearing/shaft code SHABERTH described in Appendix C, since they will require more extensive adaptation to fit on the system than the initial demonstration codes. These analyses will include all kinds of roller bearings as well as ball bearings.

The hydrodynamic bearing codes will also be expanded for various bearing types and applications using more advanced solution schemes than in the codes used in the demonstration system. In a similar way, more advanced gear analysis codes would be available including, if possible, a special code based on a comprehensive analysis of all kinds of gears already developed in industry using a lubricant properties database covering the full range of industrial lubricants.

Also for the initial prototype system, a more comprehensive entry module will be developed. It is planned to incorporate into this module some of the artificial intelligence codes now being developed in industry for component selection and failure analysis, as they become available to this project.

Since tribological design methodology is as important as hard data in generating optimal engineering decisions, an artificial intelligence-based expert system is projected to serve as a methodology guide for the database user. The broad community of mechanical engineering users needs to apply tribological knowledge to specific, practical design or operating problems. This will be done with a Design Codes Entry Module having the following capabilities:

1. component selection
2. tribology design support
3. tribological failure diagnosis
4. operating decision support

The component selection process will be organized as follows:

1) The user is queried as to the functional purpose of the component to be chosen and is asked for inputs on application conditions (constraints). It is planned to create a ruleset which associates classes of tribo-components with these functional goals and constraints. The output will be a table of suitable choices, with some comments as to the limitations and advantages of each. The tribological literature (including trade literature) contains numerous application tables for tribo-components, and the assembly of a suitable ruleset does not appear to offer insurmountable difficulties.

2) If available, the user is next offered access to on-line catalog databases of tribo-components. Such catalogs are now being created by a number of major vendors and can be linked up as they become available. From the catalog(s), the user can select one or more apparently suitable specific component types. If available on-line, the entry module reads in the characteristic catalog parameters given for each, retaining this information for future use.

3) The user is then offered access to engineering calculation programs or design codes as explained below.

The full Design Codes Database will provide design support by means of a series of calculation programs for the dynamics, lubrication, life prediction, and heat balance of major tribo-components. The Entry Module will offer access to these calculation routines through two channels: a) directly, without interaction with the component selection routine, and b) within component selection and after catalog review. Tribology design support is conceived as a tool for the selection of materials, configurations, manufacturing methods, and operating rules useful during design of a special component adapted to meet a set of generically defined tribological requirements. The art of building artificial intelligence systems for machine design is not as well advanced as that of diagnostic or list selection expert systems. The task of providing a design support system is thus a major development task in component technology. To be able to utilize such a system, a strong and comprehensive materials, configuration, and methods database must be available for access.

Failure diagnosis expert systems for tribo-components are feasible. Diagnostic systems for other branches of engineering are in operation. Proprietary work on tribological diagnostic systems is under way. Thus, access to diagnosis via the entry module will become feasible in time. The concept of providing computerized support for operating decisions involving tribology was generated at the workshop and is certainly attractive. Such a system is intended to guide an engineer in charge of operating a machine or mechanical system towards operating and maintenance practices soundly based on tribological principles.

CHAPTER 8

NUMERIC DATABASE FOR SOLID TRIBOLOGICAL MATERIALS

Group Members: William Ruff, Chairman
Raymond Bayer
Walter Grattidge
Stephen Hsu
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Marshall Peterson
John Rumble
Donald Shafer
Paul Swanson
Harald Tischer
Gordon Wood

Background

A numerical database would be an important part of a Tribology Information System, and possible configurations were discussed at length during the workshop. Two sessions were held specifically for that purpose: one on numeric data for solid materials; the other on numeric data for lubricants. This chapter will describe the discussions for numeric data for solid materials.

Members of the committee had differing viewpoints on the use of numeric tribological data, but all agreed that the issue was a very important one and that little was being done at present to satisfy the user needs. The data were identified in two categories: tribological data (friction, wear, etc.) and physical properties data (strength, toughness, etc.) on tribological materials. The materials of interest differed among the users present for these discussions. Some typical applications for numeric tribological data on solid materials include:

- general engaging tools and bearings exposed to abrasive contaminants

- office equipment and recording systems

It was pointed out that designers always need to know what has been used before and what the results were. They want to match the needs of the application with the properties of the tribo-materials. Properties such as surface characteristics, friction coefficient, and wear behavior were the prominent ones. Important issues were the application environment, geometry, lubricant coverage, roughness, temperature, load, and surface speed. Based on experience, it was felt that the industrial designer was an important customer, perhaps more so than the experienced tribologist.

User Community

There was general agreement that nonexperts in tribology were in need of useful, evaluated tribological data. These included design engineers, product engineers, and support engineers involved in a broad range of activities in industry. It was also thought that tribologists would want access to such databases as they are assigned to help solve particular problems. In fact, a hierarchy of users was envisaged, and the details would have to be understood through some sort of specific questioning of prospective customers. In that way the database could be properly configurated. It was noted that the recent Industrial Research Institute meeting on tribology stated among its recommendations that a computerized database is needed where text, graphics, equations, and numbers can be obtained.

Technical Plan

A logical, systematic framework is needed to properly compile and store the tribological data in a computer-based system. A sample format sheet for data was developed following the well-known work of Horst Czichos in Germany. That approach was extended and modified based on the experience of those present. The recommended format is shown in Figure 8-1. It contains descriptors for the two materials involved in a tribo-contact and for the third component, be it gas, liquid, or solid. The test information is then indicated in detail. Finally, the results of wear measurements, friction determinations, and surface damage indications are given for the various test runs. While the sheet is intended for use in laboratory measurement programs, the approach can also be used to evaluate existing data, and could include field or service-type information as well. A separate consideration is appropriate for physical properties data for use in design codes and tribological models. It was felt that such data were already available from a number of different sources and could be assembled into this system for the users. The specific information needed would depend on the codes and models to be supported; these would be determined later.

Five specific areas were identified to gain an understanding of the effort involved for numeric data on materials. They are listed below along with a description of the details involved.

(1) Wear of Materials Conferences (ASME): 1977,1979, 1981, 1983, 1985
 Approximately 500 articles on wear and friction
 Extract data from tables and figures
 Estimate one hour per article including some evaluation
 Total: 500 hours

(2) Selected articles from the Wear Control Handbook
 Select five articles
 Articles also serve as tutorial source material
 Estimate 10 hours/article to extract data and evaluate
 Total: 50 hours

Laboratory ______________________ **Date** ____________ **Test Series** ____________

Publication ID ____

		MATERIAL 1	MATERIAL 2	3rd BODY COMPONENT SOLID	3rd BODY COMPONENT GAS	3rd BODY COMPONENT LIQUID
MATERIALS	General Name					
	Trade Name					
	Function (A,L,I,C)					
	Chemical Composition					
	Physical Condition					
	CA Code/Registry #					
	Surface Treatment					
	Geometry					
	Roughness					
	Condition(process)					
	Supply Rate					
	Hardness					
	Density					

		RUN 1	RUN 2	RUN 3
TEST	Mechanism			
	Use/Application			
	Load (N)			
	Normal Pressure (MPa)			
	Velocity (m/s)			
	Sliding Distance			
	Motion			
	Test Type			
	Contact Area			
	Contact Ratio			
	Temperature			
TRIBO DATA	Wear Vol1			
	Wear Vol2			
	Weight Loss1			
	Weight Loss2			
	Dimension Loss1			
	Dimension Loss2			
	Wear Rate			
	Wear Coefficient			
	Friction			
	Curves			
	Life			
	Surface Damage			
	Wear Debris (Type, Size)			
OTHER	Cleaning Methods			
	Special Test Features			

Possible Format for Tribological Data

Figure 8-1

(3) ASTM standard abrasive wear test data
G-65 method; research reports and interlab test reports
Estimate 250 standard tests and 500 nonstandard tests
Estimate 15 minutes per test to code data without evaluation
Total: 200 hours

(4) Canadian wear tests in water
Nuclear reactor program results on particular materials
Estimate 1000 tests available
Estimate 15 minutes to code data without evaluation
Total: 250 hours

(5) Additional sources for data were identified for future efforts. These included international journals on tribology, standard bench test data sources such as ASTM Research Reports, and private databases from cooperating laboratories in government and the private sector.

It was emphasized that several important features were involved in addition to the data themselves. These include (1) an agreed database format, (2) use of consistent units in the base, (3) an agreed thesaurus of terms and unit conversions, (4) agreed software for computer access and data processing, and (5) determination of output forms such as tables and graphs.

Interaction With Other Efforts

The Design Task area will require support from the numeric data task in terms of values for parameters used in the design codes. Specific needs will be decided as the work proceeds. Sources for these data will be handbooks and existing physical properties databases.

The Bibliographic Task area will be developing a Tutorial System consisting of "expert" articles for users of the total information system. It is intended that some of those articles come from the Wear Control Handbook and that the numeric data associated with them be placed into a numeric database for general use. The authors themselves would be responsible for the evaluation of the data.

The Numeric Data Task on Lubricants would interact closely with this task in all aspects so that the same format and type of content would be involved.

Remaining Issues

Some of the more significant questions to be decided are summarized below. It will be essential to obtain early reaction from the tribological community and from prototype users so that these issues can be addressed.

Identification of centers to provide and evaluate data
Degree of evaluation appropriate for the different types of data
Allocation of resources within the total package of needs
Sources of financial support for database compilation
Schemes other than the computer network for dissemination of data

CHAPTER 9

NUMERIC DATABASE ON LUBRICANTS

Group Members:	E. E. Klaus
	S. M. Hsu
	S. Jahanmir
	Frances Lockwood
	J. Molgaard
	D. Shafer
	V. Weedeven

This committee considered the following areas with respect to lubricants and lubricated systems: users, components, materials, lubricants, properties data, performance data, additives, and system.

Some principal issues in considering these areas included data access (architecture), data organization (format), data analysis, and data evaluation. The committee discussed the entire project of a computerized Tribology Information System as well as a thin slice or demonstration sample of the whole project. Based on the computerized information now available, the committee favored as a "thin slice" or prototype either lubricants for journal bearings or lubricants for rolling element bearings.

The list of potential users is shown in Table 9-1. This list includes organizations as well as types of individuals.

A Lubricated Components list is shown in Table 9-2. Lubricated Systems are shown in Table 9-3. Lubricant Types are shown in Table 9-4. Lubricant Additives are shown in Table 9-5. A list of Lubricant Properties is shown in Table 9-6. A list of materials with which these lubricants must be compatible is shown in Table 9-7.

A failure analysis database is similar to that for designing to meet special requirements. In this case, structural analysis, materials properties, environment, operating conditions, parts and debris analysis, chemical analysis, and mechanism determination are needed along with the tribological database.

A sample of a data sheet for the lubricant numeric database is shown as Table 9-8. The committee discussed formats for the database. It was suggested that the approach used in Neale's handbook on tribology [2] be given serious consideration.

The committee considered the numeric database to be of major importance to the proposed system. The utility of the overall system probably hinges on the ability to produce a numeric database that proves easy to use by the people listed in Table 1. In order to meet this constraint, it appears that a large amount of interpretative and correlative work will be required on the numeric data. This comment applies equally to the thin slices suggested by the committee as well as the total database. The opinion was expressed that underfunding of the numeric database would lead to little effective use of the system.

Table 9-1

POTENTIAL USERS OF A COMPUTERIZED TRIBOLOGY INFORMATION CENTER

ORGANIZATIONS	INDIVIDUALS
Government Research Labs	Consultants
Defense Bases	Bearing Designers
Research Laboratories	Component Designers
Industrial	System Designers
	Application Engineer
Research Labs	Maintenance Engineer
Development Department	
Maintenance	Failure Analyst
Sales Engineering	Purchasing Agents
	Development Engineers
Universities	Lubricant Supplier
Libraries	Sales Engineer
Consulting Consortia	

Table 9-2

LUBRICATED COMPONENTS

Hydrodynamic Bearings	Couplings
Rolling Element Bearings	
Cams and Gears	Material Working
Clutches and Brakes	Cutting
Shaft and Face Seals	Grinding
Fluid Dampers	Polishing
Shock Absorbers	
Hydraulic Pumps	Material Forming
	Casting
	Forging
	Rolling
	Drawing

Table 9-3

LUBRICATED SYSTEMS

Reciprocating Engines	Steam Turbines
	Tractor Hydraulics
Gasoline	Aircraft Hydraulics
Diesel	Automatic Transmissions
Marine Diesel	Hypoid Gear/Transaxles
2 Cycle	Gear Reducers
Gas Turbines	

Table 9-4

LUBRICANT TYPES

Mineral Oils	Silicates
Animal Oils	Silicones
Vegetable Oils	Perfluoro Polyethers
Synthetics	Halocarbons
Polyalpha Olefins	Water Base
Alkylated Aromatics	Water-Glycol
Organic Acid Esters	Greases
Phosphate Esters	Gases
Polyglycolethers	Solid Lubricants
Glycols	Coatings
Polyphenyl Ethers	Surface Modification

Table 9-5

LUBRICANT ADDITIVES

Polymeric Viscosity Index Improvers	Antiwear
Oxidation Inhibitors	Antifriction
Corrosion Inhibitors	Extreme Pressure
Rust Inhibitors	Pour Depressants
Detergents	Solubilizing Agents
Dispersants	Dyes

Table 9-6

LUBRICANT PROPERTIES

PHYSICAL	CHEMICAL
Rheology	Thermal Stability
Volatility	Hydrolysis
Density	Oxidation Stability
Gas Solubility	Neutralization Number
Thermal Conductivity	Electrical Properties
Specific Heat	Surface Tension
Bulk Modulus	
Coefficient of Thermal Expansion	

PERFORMANCE
Chemical Degradation
Corrosion
Solvency
Low Temperature Properties
Friction
Wear
Filterability
Foaming

Table 9-7

MATERIALS FOR LUBRICANT COMPATIBILITY

Metals	Wood
Ceramics	Hard Coats
Composites	Surface Modifications
Polymers	Others
Elastomers	

Table 9-8

NUMERIC DATABASE

MATERIALS	TEST CONDITIONS	TRIBO DATA	REFERENCE PROCEDURES
Metals	Temperature	Wear Volume 1	API
Ceramics	Load	Wear Volume 2	ASTM
Composites	Normal Pressure	Weight Loss 1	Federal Test
Elastomers	Velocity	Weight Loss 2	DIN
Polymers	Motion Type		UOP
Coatings and		Sliding Dist	CRC
surfaces	Test Type	Dimension Change 1	Others
Others	Contact Ratio	Dimension Change 2	
	Surface Damage	Wear Rate	
Solids 1 and 2	Atmosphere	Friction Curves	
Properties	Moisture	Wear Debris	
Lubricants		Torque	
Additives	Test Procedure		
	Duration	Corrosion	
Component Type	Sample Treatment	Oxidation	
System Type	Film Thickness	Low Temp Properties	
	Simulation		
	Contaminants	Lifetime	
		Base Line Reference	
		Filterability	
		Application Experience	

CHAPTER 10

BIBLIOGRAPHIC DATABASE

Group Members:

F. Kennedy, Chairman
P. Blau
J. Fries
W. Grattidge
M. Peterson
G. Reisz
M. Schade

Introduction

It is important that the modern-day researcher and engineer stay abreast of technology in his field, but this task is made very difficult by the flood of scientific and technical information. Scientific and technical literature doubles approximately every 10 years, a growth rate that has prevailed since the end of WWII. In the field of tribology, the growth in the volume of scientific and engineering information is so great that most tribologists and design engineers can no longer read all the publications that may be relevant to them. Yet keeping current and informed is essential to developing state-of-the-art technology and advancing the science of tribology.

Writing in the premier issue of Journal of Tribology, Donald Hays recently underscored the need to be aware of current technology. "There is an additional technology gap which should be mentioned . . . The science exists, the technology is in place, but the potential user is unaware of the state of the art of the technology. In this case we run the risk of supporting a technical program which recreates that which already exists."[3] By not knowing about, and taking advantage of, recent developments in the field of tribology, research efforts are being duplicated and state-of-the-art tribological solutions are not being adopted. This can be very costly, especially in terms of energy losses, wasted materials, and machine downtime.

Much of the world's science and engineering literature, including that dealing with tribology, is now covered by online bibliographic databases. Computer-based information retrieval from these online databases can significantly speed and ease the process of collecting bibliographic information. By making use of this tool an engineer can save time, enhance productivity, and aid in the transfer of technology. There is evidence that, for a number of reasons, tribologists and other engineers have not been taking advantage of this availability and that they are not completely aware of advances in the field of tribology.

Anticipated Users of the System

The potential users of the proposed Automated Tribology Information System could be grouped into five classifications:

(1) tribology specialists
(2) materials generalists
(3) design engineers
(4) librarians and other information specialists
(5) students

These different groups may be interested in different bibliographic information, with, for example, the first group being most concerned with technical journals and conference proceedings while the third group would require books and articles of a more applied nature. It was felt that an entire information system must aim to serve needs of the broad industrial community composed of groups (2) and (3) if it is to carry out its primary technology transfer role and to become self-supporting by developing reasonably priced subscriptions. The task group believed that the bibliographic needs of those industrial users could be served without compromising the requirements of the other, more specialized groups of potential users. Therefore, the bibliographic task group attempted to design a system that would serve well the entire spectrum of potential users of the ATIS, both in its prototype and final versions.

It was believed that many of the users of other portions of the proposed Tribology Information System would benefit from easy access to bibliographic information while connected to the system. For example, users of the research-in-progress module (who would probably be accessing a database very similar in nature to the bibliographic databases) may wish to search for publications resulting from the research-in-progress. Users of the numerical data module may wish to find more information about the article from which the data came or about the test standard used in gathering the data. Users of the design module could benefit from finding articles or reports describing the computer codes being used or the theory behind them. For this reason, this task group believed that a bibliographic module should be an integral part of all versions of the system, beginning with the initial prototype.

It was proposed that the initial prototype be made available to a selected number of evaluators/users including people from all five of the groups mentioned above. These users would be asked to evaluate the bibliographic search system included in the prototype stage and to suggest improvements for later implementation.

Available Bibliographic Sources in Tribology

The published literature in tribology, consisting primarily of books, articles in technical journals, reports, patents, and standards, has been expanding at a rapid rate in recent years. It is estimated that about 6000 technical papers and several hundred books and reports are being published annually dealing with some aspect of tribology. Although a guide to these sources of information was published in 1974 [4], the information has been

growing so rapidly that the guide is already out of date and, even if it weren't, it would be nearly impossible for anyone to keep up with all new published information in the field. To aid in the task of searching the literature for information about a topic, indexing and abstracting services were developed. These services usually include abstracts of each article and use prescribed index vocabulary (keywords) to describe the article's content. Within the past 15 years, many of the abstracting/indexing services have become available online, and it is these online bibliographic databases that were the focus of this task group's attention.

A recent study showed that just over 20 of the widely accessible bibliographic databases have good coverage of the field of tribology [6]. Those databases, and a brief description of each, are listed in Table 10-1. All could be classified as bibliographic databases since they contain references to published articles, reports, or books, but not the full text of the articles.

Little technical literature is currently available in full-text (or source) databases, but this may change if source databases increase their coverage of engineering in response to requests from users.

Most of the databases listed in Table 10-1 and their associated print counterparts cover technical journals or reports, but several are included which deal with other forms of technical literature such as dissertations, patents, or standards. Some are wide-ranging, and their coverage extends to all areas of engineering. For example, NTIS, COMPENDEX, and EI MEETINGS are broad databases which cover government reports, technical journals, and conference papers, respectively. Although they are frequently a good place to begin a search of the engineering literature, their coverage in any particular area of tribology may not be as thorough as that given by a more specialized database.

The narrower bibliographic databases, such as BHRA FLUIDEX, APILIT, and METADEX, all contain references to the worldwide technical literature, but each concentrates on the literature of a certain field (fluids, petroleum, and metals, respectively). In those three databases, journal articles are abstracted and indexed selectively, according to the subject scope and emphasis of the database. Within their special areas of interest, the coverage of the narrow-range databases is apt to be quite comprehensive, although coverage of a journal by a specialized database does not imply abstracting/indexing of each article in every issue of a journal.

Database TRIBO, the online equivalent of TRIBOLOGY INDEX, is the only database devoted specifically to tribology literature. It is produced in West Germany by BAM and includes extensive coverage of the tribology literature of Eastern Europe and Asia [7]. A recent survey showed that TRIBO covered more of the non-US tribology journals than did any of the American databases listed in Table 1 [6]. Where most of the other bibliographic databases in Table 1 include abstracts and are indexed by a set of keywords, base TRIBO has no abstracts and employs a different classification scheme that includes tribological information about the articles. It is noted that there is a companion database to TRIBO, base RHEO, which deals with the

subject of rheology, or deformation and flow of materials, including lubricants. Its format and accessibility are similar to those of base TRIBO.

Access to bibliographic databases as listed is generally provided by a commercial search service or database vendor. Four of the vendor services that are widely accessible within the U.S.--BRS (BRS, Inc.), DIALOG (Dialog Information Services, Inc.), SDC (SDC Information Services), and STN (Chemical Abstracts Service)--provide access to one or more of the databases listed. Database TRIBO is currently accessible only through a German online service, INKA Karlsruhe, which can be accessed from the U.S. through an international communications network. Sometime in 1987 or 1988 the TRIBO and RHEO databases are scheduled to become available in the U.S. on the STN network.

The NASA database, which contains references to literature for aeronautics and astronautics, respectively, is completely accessible through NASA/RECON. The DOE Energy Data Base has a current one-year window available through OSTI/ITIS. Access is allowed primarily to staff or contractors of those agencies. Recently, however, two of the databases in the NASA family, IAA and STAR (AEROSPACE DATABASE), became available through Dialog while the most relevant of the DOE databases, DOE ENERGY, became available through both Dialog and STN. The OCLC database, which contains references to books held by the member libraries, is an enormous database, but it is only accessible to member organizations.

Deficiencies of Available Bibliographic Sources

As is clear from the above discussion, the currently available online bibliographic databases could satisfy most of the needs outlined in the introduction above. Searches by members of this task group on tribological topics have shown that just about all recent tribology literature of any significance is indexed on one or more of the databases listed in Table 10-1. Because of the different coverages of the various databases listed in the Table, however, it is usually necessary to search several databases to get references to all literature on a subject. This is relatively easily done at the present time if all of the databases of interest are served by the same vendor. If different vendor services need to be consulted, the search becomes more complicated and requires computer access to each of the online search services.

Another difficulty encountered in doing multiple-database searching is that the same article may be indexed with different keywords on different databases. In fact, the most comprehensive coverage of tribology is provided by database TRIBO, which uses a classification scheme quite different from the keyword indexing used by most other databases.

Another problem with the available bibliographic databases can be seen in Table 10-1. None of the online databases covers literature published before the mid-1960s, and most cover only post-1970 publications. There are many significant tribology publications that are more than 15 years old, and a complete search of the literature ought to include those references.

Table 10-1

CURRENTLY AVAILABLE BIBLIOGRAPHIC DATABASES
DEALING WITH TRIBOLOGY

Database Name and Online Coverage	Producer	Online Vendor
Journals, Reports, & Books		
TRIBOLOGY INDEX (1972-date)	BAM, Berlin	INKA Karlsruhe
COMPENDEX (1970-date)	Engineering Information, Inc.	BRS, Dialog, SDC
NTIS (1964-date)	National Technical Info. Serv.	BRS, DIALOG, SDC
METADEX (1966-date)	ASM and The Metals Soc.	Dialog, SDC, STN
BHRA FLUIDEX (1974-date)	BHRA Fluid Eng'g Centre	Dialog
EI ENG'G MEETINGS (1982-date)	Engineering Information, Inc.	Dialog, SDC
CA SEARCH (1967-date)	Chemical Abstracts Service	STN (BRS, Dialog, SDC)
APILIT (1964-date)	American Petroleum Institute	SDC
NASA (1962-date)	NASA and AIAA	NASA/RECON (Dialog)
SCISEARCH (1974-date)	Inst. for Scientific Info.	Dialog
ISMEC (1973-date)	Cambridge Scientific Abs.	Dialog
DOE ENERGY (current year)	Department of Energy	DOE/ITIS
DOE ENERGY (1974-date)	Dept. of Energy	Dialog, STN
SAE ABSTRACTS (1965-date)	SAE	SDC
INSPEC (1969-date)	Inst. of Electrical Eng'rs.	BRS, Dialog, SDC
DISSERTATION ABS. (1961-date)	Univ. Microfilms, Inc.	BRS, Dialog
ONLINE COMPUTER LIBRARY CNTR.	CCLC	CCLC
Patents		
APIPAT (1950-date)	Amer. Petroleum Inst.	SDC
CLAIMS/US PATENTS (1963-date)	IFI/Plenum	Dialog
PATSEARCH (1970-date)	Pergamon InfoLine	Pergamon
World Patents Index(1963-date)	Derwent	Dialog, SDC
Standards		
INDUSTRY & INT'L STANDARDS	IHS	BRS
MILITARY & FED SPECS STDS	IHS	BRS
STANDARDS & SPECS	Nat'l Standards Assoc.	Dialog

The bibliographic task group felt that all of the difficulties mentioned above require attention. Another problem that the group felt must be addressed if the bibliographic module is to be attractive to design engineers is ease of use. At the present time, much bibliographic searching is done by librarians or other information specialists who have become familiar with the specialized vocabulary used in database searching. It was felt that the system must appeal to a broad spectrum of users, not just information specialists, and that those users should not have to learn special search terms for each database. The users should be aided in their choice of databases to search and then should be able to do the search using "natural language," if possible.

Bibliographic Tasks and Work Statements

In order to remedy the deficiencies described above and to make bibliographic search capability an integral part of the Tribology Information System, this task group proposed that six major tasks be undertaken. These tasks would be divided into subtasks scheduled for completion at various stages in the development of the System. The tasks are described in Chapter 16 .

CHAPTER 11

PRODUCTS AND SERVICES DATABASE

Group Members: William J. Anderson, Chairman
Richard S. Fein, Chairman
Christie Michelsen
Lewis B. Sibley
Robert C. Tucker

Introduction

There is a need for a products directory in a tribology information system because (1) no presently available directory is adequately broad and deep to meet the needs of tribologists, and (2) the computer can provide information on the sources of commercially available tribological products and of tribologically related services.

The users of directory information were identified as application, maintenance, design, etc. engineers and purchasing agents. Directory information on products should be adequate to enable a user with a profile of product requirements to select a list of products satisfying the requirements. It should also provide the user with a contact address and phone number for suppliers of the suitable products; this would enable the user to contact suppliers for the price, availability, technical support, etc. information needed to make an economically and technically sound product choice.

In many cases, users need help in design or decisions. Also, users sometimes need or find it attractive to hire services to supplement in-house skills or to provide additional help during periods of peak activity. Hence, there exists a need for a single directory of services directed explicitly at tribological needs.

Technical Plan

Table 11-1 shows the scope of the Products and Services Directory. However, even though the capability exists to make available catalogs or their summaries as well as the other information discussed below, there is the question of whether or not a real demand exists and if enough information could be included economically. Consequently, the first priority should be to contact the user community and the supplier community to better understand their participation. This could take the form of an initial relatively inexpensive solicitation of catalog information in computer-readable form (with the understanding that the vendor would be charged a fee for having a catalog in the information system, once on-line). In addition, business and economic issues should be settled before work begins.

Table 11-2 lists the general contents of the Products and Services Directory. Tables 11-3 through 11-8 provide a noncomprehensive listing of at least the major subcategories for each of the types of products in the general contents.

Table 11-5 classifies surface and substrate materials by kind and fabrication/manufacture technology. Table 11-6 classifies lubricants by the commonly used kind, industry or application, and specification that is satisfied.

At present, neither catalogs nor reference books contain adequate tribological data on commercially available materials and lubricants. Consequently, in addition to catalog data, the Directory activity should attempt to obtain the additional data that the product suppliers commonly will release to customers. This physical, chemical, and tribologically significant performance data on commercial products would be incorporated into the Numeric Data Base module and substantially augment its value to System users. Procurement of these types of data appears to hinge on convincing at least one leading supplier in each major project grouping that his interests are served by providing the data. Competitors are likely to then supply their data for competitive reasons.

Lubricant and material recovery, reuse, and disposal are becoming increasingly important to tribologists and to manufacturers and users of tribological devices. The increase in importance primarily results from hazardous waste regulations required by the Resource Conservation and Recovery Act (RCRA). Implementation of the RCRA Amendments of 1984 over the next several years will increase the number of affected businesses tenfold. At present affected businesses are finding that the cost of handling lubricant and material waste exceeds the original cost. Table 11-8 lists major categories for waste handling.

The services information in the Directory would be made more useful than the many existing directories (e.g., Yellow Pages, Thomas Register, Machine Design Reference Issues, Pollution Engineering, etc.) by thorough breakdown into tribologically important categories. Table 11-9 shows the listing format for service vendors.

Legal Aspects of Technical Plan

Directory information needs to be obtained, installed, and recovered with due regard to legal implications. From antitrust and restraint of trade considerations, it appears that all vendors must have the opportunity to provide information to the Directory. It also appears that requirements for product characteristics (product profile) produced by the ATIS Design module must generally be satisfied by products from a number of competing vendors.

Opening Directory input to all vendors probably can be legally accomplished by advertising in the Commerce Business Daily and leading technical and trade publications in tribologically related fields.

Product profile satisfaction by a number of (often many) competing products should not represent a problem. The type of product required as generated from the user's assessment of requirements or as output from the Design module generally will provide the user with the basis for selecting among products. The Directory will provide the user with a list of vendors whose products meet his/her performance requirements and enable a selection on the

basis of other requirements (price, availability, other technical considerations, etc.) than those needed for the tribological design.

Liability to vendors and users is another legal consideration. It appears that potential problems may be eliminated by making the vendors responsible for the accuracy of their input. This could be accomplished by requiring that input data be supplied in machine-readable form.

Table 11-10 summarizes the vendor data input requirements that appear to the Group to limit potential legal problems. Advice of counsel needs to be obtained before proceeding very far in detailed Directory planning.

Table 11-11 is a first-cut attempt at a data input form that will satisfy both the Directory and Numeric Data Base requirements for products. The form needs considerable refinement to make sure that it is comprehensive, consistent with the Numeric Data Base input form, and is easy to use by vendors.

Table 11-12 summarizes the types of user inputs and outputs from the Products and Services Directory.

Financial Plan

Monetary contributions from government and from major industrial manufacturers and major suppliers of products and services will support development of the Thin-Slice Prototype. In-kind contributions of machine-readable, specific format catalog and additional numeric data will reduce the Directory cost manyfold.

Full-scale implementation of the Products and Services Directory will be made self-supporting by the requirement for machine-readable input data and by imposition of data storage fees. It is anticipated that companies providing data will treat this as advertising.

Table 11-1

PRODUCTS AND SERVICES DIRECTORY

Provide Engineers, Purchasing Agents, Etc.
Sources of Tribological-Related Products
and Services

* Enough Product Technical Detail to Enable
  Selections Meeting Many Profile Requirements

  Contact Address/Phone for
  Price, Availability, Etc.

* Technical Support
  Consultants Directory
    Name
    Field of Specialty
    Contact Address/Phone

Table 11-2

PRODUCTS AND SERVICES DIRECTORY

CONTENT

* Components (1)
* Predominantly Tribological Assemblies (1)
* Materials (2)
* Lubricants (2)
* Lubrication Systems (1)
* Lubricant Recovery/Reuse/Disposal
* Consultation/Engineering Services
* Maintenance Services
* Coating Services
* Lubricant and Material Recovery/Reuse/Disposal Services

(1) Interacting with Design Data Base
(2) Interacting with Numeric Data Base

Table 11-3

COMPONENTS

* Rolling Bearings
* Sliding Bearings
* Gears
* Seals
* Clutches
* Brakes
* Couplings
* Fluid Dampers
* Cams
* Valves

Table 11-4

PRINCIPALLY TRIBOLOGICAL ASSEMBLIES

* Gear Boxes
* Speed Increasers/Reducers
* Pumps
* Hydraulic Motors
* Compressors

  Etc.

Table 11-5

MATERIALS - SURFACE/SUBSTRATE

* Substrate Metal
  - Metal Heat Treatment
    - Porous Metal
    - Graphite
    - Polymer
    - Ceramics
    - Composites
* Surface Treatment
  - Heat
  - Mechanical
  - Diffusion Coating
    - Carburizing
    - Nitriding
* Overlay Type Coating
  - Plating
  - Thermal Spray
  - . . .
  - PVD
  - . . .
  - CVD
  - . . .
  - Hardfacing (Fusion)
  - Welded
  - Brazed
  - Spark Transfer
* Polymer Bonded Material

Table 11-6

LUBRICANT CLASSIFICATIONS

* Kind
  - Oil
  - Grease
  - Coolant
  - Solid
  - Self-Lubricating Material
  - Additives

* Industry/Application Classes

Automotive	Aviation
Industrial	Marine
Gear	Railroad
Transmission and Torque	Fluids
Engine Oils	Coolants
Metal Cutting	Metal Forming

* Specification
  - Military
  - Major OEM
  - SAE
  - ASLE
  - AGMA
  - API

Table 11-7

LUBRICATION SYSTEMS

Wick	Filter
Splash	Pumps
Central	Valves
Liquid	Pressure Regulators
Mist	Chip Detectors
Oil/Grease Cups	Condition Monitoring
Heat Exchangers	Leak Detection

Table 11-8

LUBRICANT AND MATERIAL RECOVERY, REUSE, DISPOSAL

Collection

Storage

Treatment
- Physical
- . . .
- Chemical
- . . .
- Biological
- . . .

Transportation

Disposal

Systems
- Recovery
- Reconditioning
- Waste Treatment

Table 11-9

SERVICES RECORD FORMAT

* Name
* Type of Service(s)
* Location
* Phone
* Other Tribo-Related Information

Table 11-10

INPUT REQUIREMENTS FOR COMPREHENSIVE DIRECTORY

* Vendor Supplies Input Data in Machine-Readable Form

* Open to All Vendors Willing to Meet Data Input Requirements (Data Storage Fee)

Table 11-11

PRODUCTS AND SERVICES DIRECTORY

		Requirement Profile			Vendor Contact
		Specification			Price, Availability, Etc.
USER INPUT	--→	Application	USER OUTPUT	---→	Technical Support
		Product			Catalog Data (Design Data Base)
		Service			Numeric Data (Numeric Data Base)
					Product-Specific
					Product-Type Statistics

CHAPTER 12

RESEARCH-IN-PROGRESS DATABASE

Group Members: Marshall Peterson, Chairman
Mark Fornwall
Walt Grattidge
Said Jahanmir
Fran Lockwood
Dora Moneyhun
Don Shafer

Background

A Research-in-Progress database is being considered as part of a computerized Tribology Information System. This database would contain abstracts of current (unpublished) tribology research being conducted by government, industry, universities, and research institutes and would be available on-line to interested parties. Such a service would be of primary interest to researchers and especially those who fund research in tribology so they could avoid duplication. Even more important, they could leverage their efforts by funding work in progress. Both government and industry would find it beneficial, but industry participation would be limited because of proprietary interests.

Database

Some RIP databases currently exist and are available on-line, such as the Smithsonian Scientific Information Exchange (now defunct) and the Defense Technical Information Center's Work Unit Information System. DOE also operates a RIP database containing research relevant to energy. It seems logical to conclude that the DOE system should be used. This database is built on several sources of information. First, all the contractors including the national labs have a contractual requirement to submit yearly a form (538) describing research in progress. In addition, other sources of information are used to give good coverage of DOE research. Currently, there are 11,000 records on-line which are available through DOE/ITIS at OSTI or through Dialog using their Federal RIP database. The Federal RIP (from NTIS) contains 66,200 records from a variety of agencies. The DOE RIP is searchable by subject, author, organization, descriptors, and a variety of other fields. It allows continual updating.

During the workshop, the panel studied and used the DOE RIP database. The available formats and a typical record are shown in Table 12-1. Use of the RIP database to conduct several searches indicated that it was completely satisfactory except that the subject thesaurus did not adequately cover the field of tribology. This was expected, however, since most databases were considered inadequate in this regard. The primary problem seems to be that certain words have special meanings for tribologists. Subsequent to the workshop, the subject thesaurus was reviewed. Neither tribology nor any of its related terms (bearings, friction, lubricants, synthetic lubricants, or

Table 12-1

AVAILABLE FORMATS

0 Full record
1 Accession number
2 Title, principal investigator data, contract no., project status, start date, funding and monitoring organizations, descriptors
3 Brief record: source, title, corporate source, contract no., project status, funding and monitoring organizations, BRCC code
4 Title, organization, project status
5 Title, principal investigator data, contract no., project status, start date, funding and monitoring organizations, subject category, abstract, publications
6 Title, organization, project status
7 Organization, project status, BRCC code

TYPICAL RECORD

	<ACCESSION NO.> 83R0000251
	<TIC ACCESSION> 000251
SO-	<SOURCE> WPAS-251
TN-	<TAPE DATE> 84/03/06
/TI	<TITLE> Electromagnetic Isotope Separation
PI-	<PRINCIPAL INV.> Bell, W.A., Jr.; Tracy, J.G.; Caudill, H.H.; Ottinger, C.L.
	<PI PHONE> C615-574-0432;F624-0432;C615-574-0430;F624-0430
CS-	<ORGANIZATION> Oak Ridge National Laboratory
	<ADDRESS> P.O. Box X
	<CITY> Oak Ridge
ST-	<STATE> TN
ZP-	<ZIP CODE> 37831
CC-	<CORP. CODE> 483 2000
MC-	<MONITOR CODE> ER-20
PT-	<ORG. TYPE> FF(FEDERALLY FUNDED R&D CENTER/LABORATORY)
LO-, CO-	<COUNTRY> TN United States
PO-	<PROGRAM OFF.> ER-20
	<ORG. CONTROL #> 00013(27)
CA-, CN-	<CONTRACT #> AC05-84OR21400
LC-	<LAB. CODE> W05-82-ER-OR-0709
PS-	<PROJ. STATUS> CONTINUING
MO-	<MONITORING ORG> USDOE Office of Energy Research, Washington, DC. Office of High Energy and Nuclear Physics
TM-	<TECH. MONITOR> Kane, J.S.
	<TM PHONE> F233-5565
AM-	<ADMIN. MONITOR> Lenhard, J.A.
BD-	<START DATE> Oct81
BR-	<BRCC CODE> KC-01-02-01-0
MP-	<MANPOWER> 21.0
FO-	<FUNDING ORGS.> DOE-83
NC- ,PC-	<SUBJ. CATEGORY> 070100;400703
/AB	<ABSTRACT> The objective of this project is to separate and provide multigram quantities of highly enriched separated stable and selected radioactive isotopes, including the actinides, to the research community. Important aspects of the program are research, development, and demonstration of cost-effective alternate methods of isotope enrichment as well as activities in ion source technology, beam dynamics, ion retention, and chemical recovery

wear) are listed as subject categories. If the DOE RIP is to be used, it is suggested that tribology be listed as a primary category with appropriate scoping.

Since the DOE RIP does not contain non-DOE entries of other government agencies, university, and industry research, policy decisions would be required of DOE to expand the RIP file. Since the workshop, these questions have been explored and no significant problems are foreseen.

A second question concerns access which is now through the OSTI gateway, limited to government agencies and contractors. The eventual system operator would have to be a DOE contractor to access OSTI through a gateway or obtain duplicate tapes. If tapes are released, they would be available to anyone. Fed RIP is available to the public through Dialog.

These problems, however, are considered minor in comparison with the advantages of a working system with available technology. Thus, expansion of the DOE RIP is the recommended approach.

The expansion of the DOE RIP must include the addition of other government tribology research and private sector research. Other government tribology research is the subject of a government report which tests approximately 200 government projects. A similar survey would have to be conducted for nongovernment research as part of the tribology information program. Updating on a yearly basis would be required. This is not a simple task since researchers tend to give such tasks a very low priority even if there is a contractual requirement. The panel considered various approaches. Although a standard form could be used and mailed to previous contributors, it was felt that a more personal approach would be required, using the technical societies. Correspondents would be named at each industry, institute, university, or government lab which conducts research. These individuals would be responsible for submitting the appropriate information on a yearly basis.

CHAPTER 13

ELECTRONIC NEWSLETTER

Group Members: Ken Ludema, Chairman
Herb Cheng
Peter Blau
John Rumble

The Newsletter will serve three functions:

1. It will be a marketing instrument for attracting potential sponsors for the Tribology Information System, in industry and government, primarily through the 70,000 members of ASME, plus designers and tribologists wherever they can be found.

2. It will be a medium of exchange of old and new technical information among tribologists and anyone with thoughts on tribology.

3. It will provide an information link between designers (in industry and elsewhere) and the developers of the Tribology Information System on specific needs of designers.

The Newsletter will be transmitted primarily by "electronic mail." Information directed to the Newsletter can be transmitted by all means of communication.

The Newsletter will be managed by an Editor. The Editor will interact with all interested "subscribers" in order to develop broad interest and involvement in the purposes of the Tribology Information System.

Features of the Newsletter will include:

1. Discussions on correlation between lab tests and the behavior of practical machinery.

2. Discussions on research topics, e.g., scuffing criteria.

3. Discussions on the quality of tribological data in the literature and handbooks.

4. Statements of the needs of designers for wear data.

5. Forum(s) on topics of interest to subscribers.

6. Discussions on glossaries and definitions of terms.

7. Discussions on developing models for wear.

8. Progress reports on the activities of the four divisions of ATIS.

9. Questions to the subscribers on the availability of design codes and on the needs of designers.

10. List of new (tribological) products of interest to designers.

11. Lists of meetings and symposia on tribology.

12. Information of government initiatives in tribology.

13. Mini-tutorials of several aspects of tribology.

14. Any other topics that will be of interest to subscribers.

PART C - TECHNICAL PLAN

CHAPTER 14

OVERVIEW

Technical Plan

The overall approach is to develop a demonstration system as soon as possible to show potential users the possibilities of an automated workstation for tribological component selection and research. Prototyping will be used to demonstrate rapidly design capabilities and act as a communications mechanism among designers and users. Figure 14-1 shows a graphic representation of the prototyping process.

Rapid Prototyping Process Model

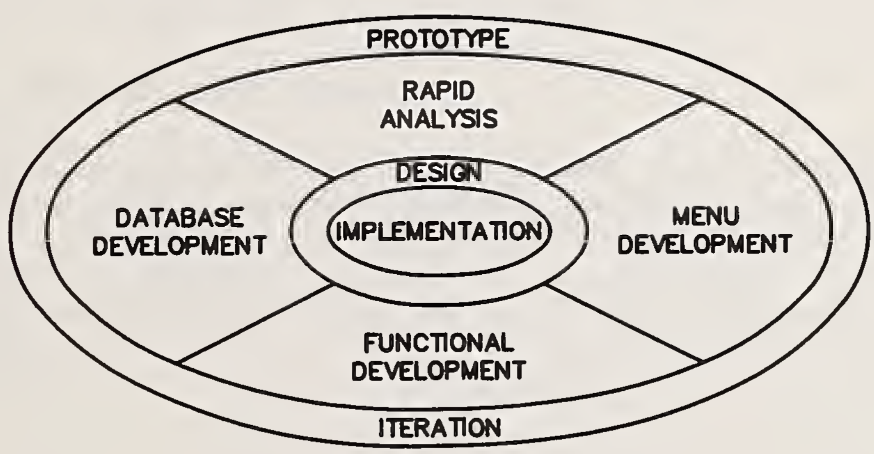


Figure 14-1

Prototype Approach

The rapid prototyping approach requires the ability to iterate, in real-time, through options for the system with the end users. This necessitates state-of-the art hardware tools and software packages for representing the customers' requirements in a real-world, automated setting, not on paper. Personal computers, database management systems, spreadsheets, communications, and graphics programs exist off-the-shelf. These can be tied together so that for less than $10,000 you can have the tools to build deliverable rapid prototypes.

Overall Architecture

The total system must be modular in that we can build on the previous work from the demonstration and prototyping phases. The design will incorporate as much off-the-shelf hardware and software as possible and enforce compatibility between new releases of the system capabilities.

User-Friendly Design Aspects

User-friendly is neither a "holy grail" nor a marketing buzzword anymore. It is available and expected at a reasonable cost. Consistent menus and access to automated tools are easily accomplished via a standard menu shell for the user. All applications, whether a communications protocol or a design code, will be accessible in a consistent manner through a menu-driven system.

CHAPTER 15

SYSTEM ARCHITECTURE

Figure 15-1 shows the following four options for hardware:

1. Host Mini With Telecommunications and Centralized Data Base

2. Distributed PC Network With Distributed Data Bases

3. Workstations With Gateway Software Resident (a la Corrosion)

4. Workstations With Host as Gateway

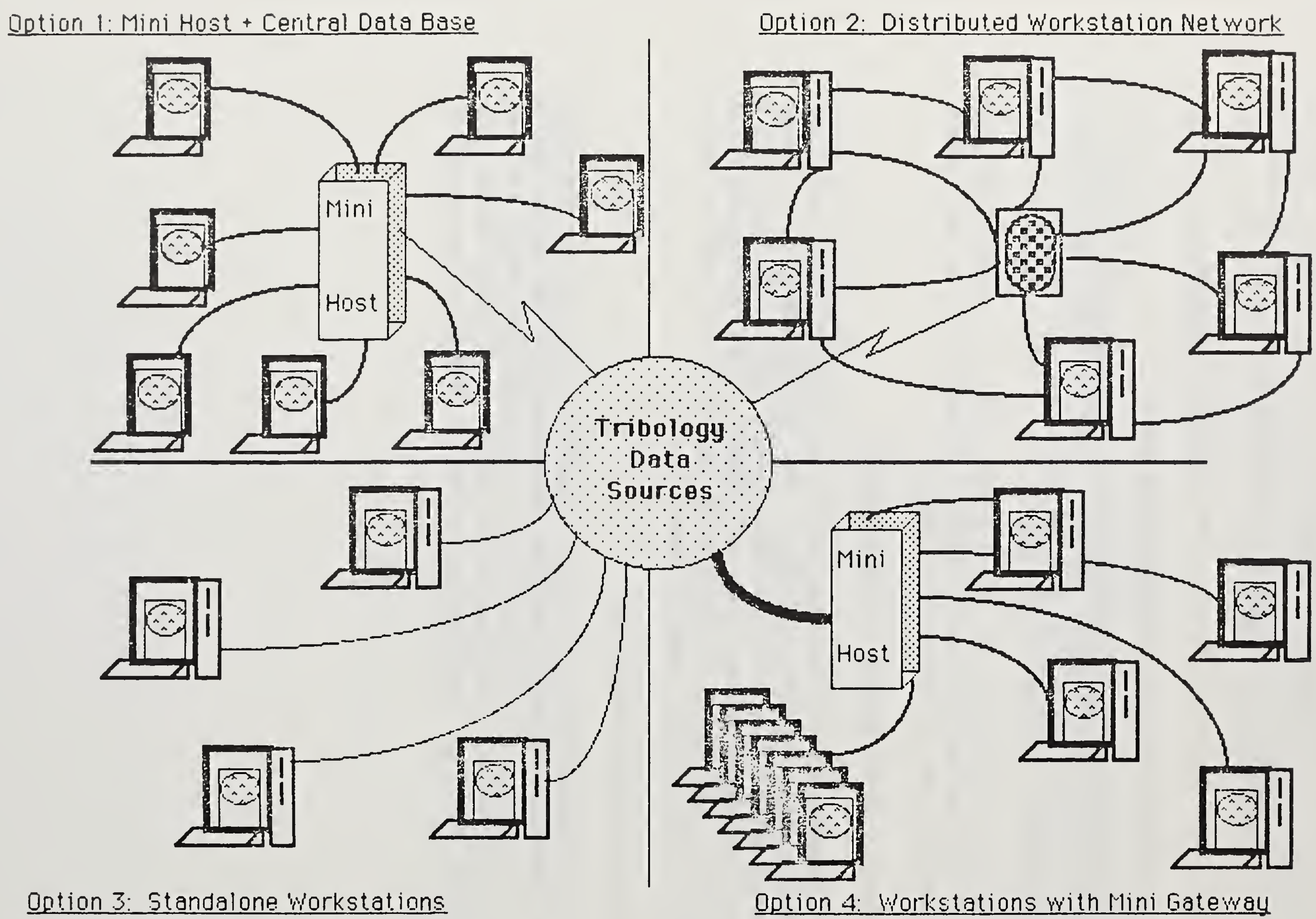
Figure 15-2 provides a qualitative evaluation of the four options. Workstations with a mini-gateway to centralized databases are the most cost-effective and expandable over the system life cycle.

Hardware Configuration - Basic Resource Requirements

Basic hardware requirements for option four would be an IBM PC/XT or compatible as the host workstation for the end-user. The gateway should be something of the class of a DEC VAX 7xx that can support electronic mail and a relational database management system such as INGRES. This workstation and gateway combination are extremely software-rich and have no lack of peripherals for plotting, graphic aids, and printers.

Software Configuration and User Interface

The system will be completely menu-driven with specific applications designed and built so that specific command language shortcuts for the experienced user may be used. Figures 15-3 through 15-17 show proposed menus for the system. In order to collect information on full user requirements for software tools, Figure 15-18 is provided as a sample checklist for requirement identification.



Hardware Options

Figure 15-1

Assumptions:
Prototype System with less than 40 users
User supplied terminals and workstations
Host system provided at no cost for hardware and data base management software

	Design Techniques	Bibliographic	Numeric	Product Directory	Research in Progress	Newsletter
Mini Host + Centralized Data Base	9 / 9	9 / 3	6 / 8	6 / 8	3 / 5	3 / 9
Distributed Workstation Network	7 / 5	9 / 0	6 / 5	9 / 6	5 / 5	3 / 7
Standalone Workstations	5 / 8	2 / 8	5 / 8	2 / 7	2 / 7	3 / 0
Workstations with Mini Gateway	5 / 8	2 / 8	5 / 8	2 / 7	2 / 7	2 / 9

Relative Usability Number 0-9	1 / 9	Relative Cost Number 0-9

Hardware Option Relative Cost and Usability

Figure 15-2

Automated System for Self-Help Information Services in Tribology - Menu Tree

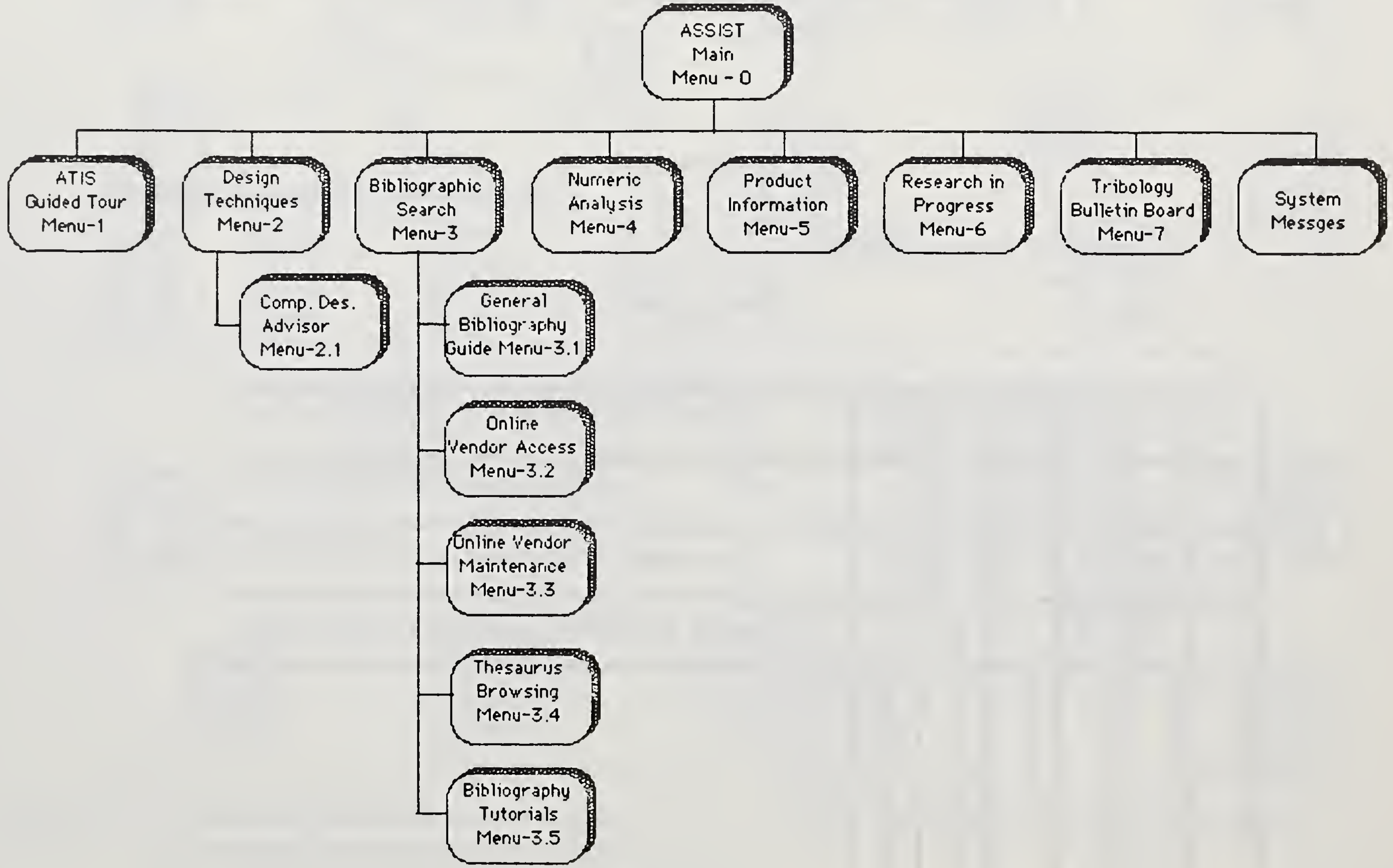


Figure 15-3

Menu 0 mm/dd/yy hh:mm:ss

Welcome to the Automated System for Self-Help Information Services in Tribology (ASSIST) Prototype

NAME:__________ PASSWORD:□□□□□□□□□□□□

SELECTION: ____

END	End this ASSIST Session
GDT	Guided Tour of ASSIST
DES	Design Techniques
BIB	Bibliographic Search
NUM	Numeric Analysis
PDT	Product Information
RIP	Research in Progress
TBB	Tribologists' Bulletin Board

Please check bulletin board for unread announcements

ATIS Menu 0 - Introductory Menu to the Automated System for Self-Help Information Services in Tribology (ASSIST).

Contains all the initial selections, system guided tour and sign-on, password verification.

Figure 15-4

Menu 1 mm/dd/yy hh:mm:ss

Guided Tour of ASSIST Prototype

SELECTION:____

RET	Return to main menu
TPP	Prototype Participants and Experts Directory
DES	Design Techniques Information
BIB	Bibliographic Search Information
NUM	Numeric Analysis Information
PDT	Product/Services Directory Information
RIP	Research in Progress Information
TBB	Tribologists' Bulletin Board Information
AST	Assistance

Figure 15-5

Menu 2 mm/dd/yy hh:mm:ss

ASSIST Design Techniques PROTOTYPE

SELECTION:____

RET	Return to main menu
CSA	Component Selection Advisor
CRN	Run Prototype Design Codes
DCE	Design Code Enhancements
AST	Assistance

Please check bulletin board for unread design technique announcements

Figure 15-6

Menu 2.1 mm/dd/yy hh:mm:ss

ASSIST Design Codes PROTOTYPE

SELECTION:____

RET	Return to main menu
RLB	Roller Rearings
HYB	Hydrodynamic Bearings
BLS	Boundary Lubricated Sliding Component
GRS	Gears
SLS	Seals
AST	Assistance

Figure 15-7

Menu 3 mm/dd/yy hh:mm:ss

ASSIST Bibliographic Search PROTOTYPE

SELECTION:____

RET	Return to main menu
BIB	General Bibliographic Functions
OLN	Online Vendor Access
OLP	Online Vendor Profile Maintenance
THE	Thesaurus Browsing
PRE	Pre-1970/72 References ???
TUT	Tutorials
AST	Assistance

Please check bulletin board for unread bibliographic search announcements

Figure 15-8

Menu 3.1 mm/dd/yy hh:mm:ss

ASSIST General Bibliographic Guide

SELECTION:___

RET	Return to main menu
FNC	ATIS Bibliographic Functions
VEN	Commercial Vendor Summaries
SOU	Tribology Information Sources
OLD	Pre 1970/72 References
AST	Assistance

Figure 15-9

Menu 3.2 mm/dd/yy hh:mm:ss

ASSIST Online Vendor Access PROTOTYPE

SELECTION:____

RET	Return to main menu
V1	User Vendor 1
V2	User Vendor 2
V3	User Vendor 3
V4	User Vendor 4
V5	User Vendor 5
AST	Assistance

Figure 15-10

Menu 3.3 mm/dd/yy hh:mm:ss

ASSIST Online Vendor Maintenance PROTOTYPE

SELECTION:____

RET	Return to main menu
ADD	Add a new vendor
DEL	Delete vendor from list
CHG	Change information on vendor
DIS	Display current vendor list
AST	Assistance

You presently have xx vendors defined

Figure 15-11

Menu 3.4 mm/dd/yy hh:mm:ss

ASSIST Thesaurus Browsing PROTOTYPE

SELECTION:____

RET Return to main menu

BRW General Browsing
SEL Select term for display

AST Assistance

Figure 15-12

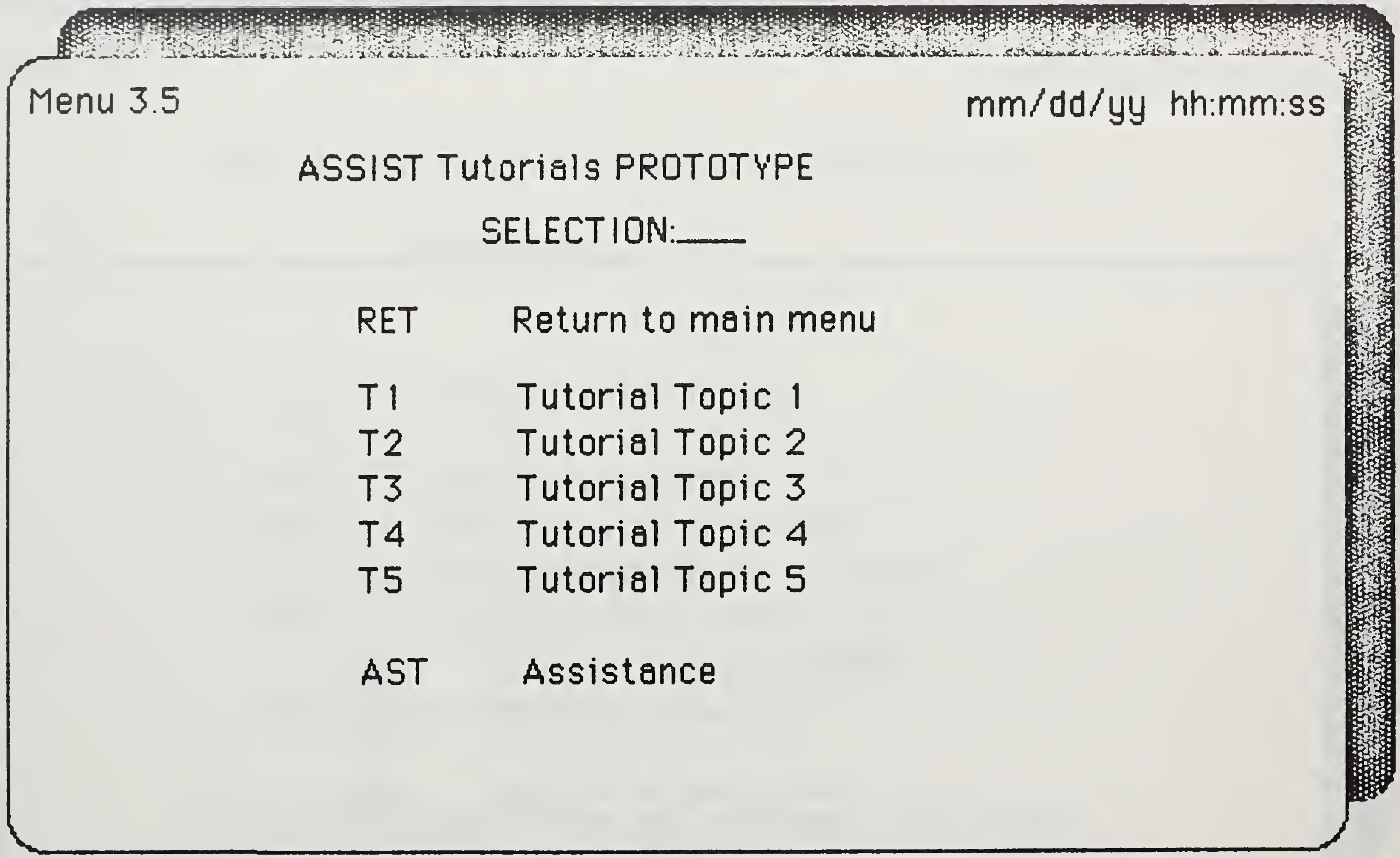

Menu 3.5
mm/dd/yy hh:mm:ss
ASSIST Tutorials PROTOTYPE
SELECTION:____
RET Return to main menu
T1 Tutorial Topic 1
T2 Tutorial Topic 2
T3 Tutorial Topic 3
T4 Tutorial Topic 4
T5 Tutorial Topic 5
AST Assistance

Figure 15-13

Menu 4 mm/dd/yy hh:mm:ss

ASSIST Numeric Analysis PROTOTYPE

SELECTION:____

RET Return to main menu

AST Assistance

Please check bulletin board for unread numeric analysis announcements

Figure 15-14

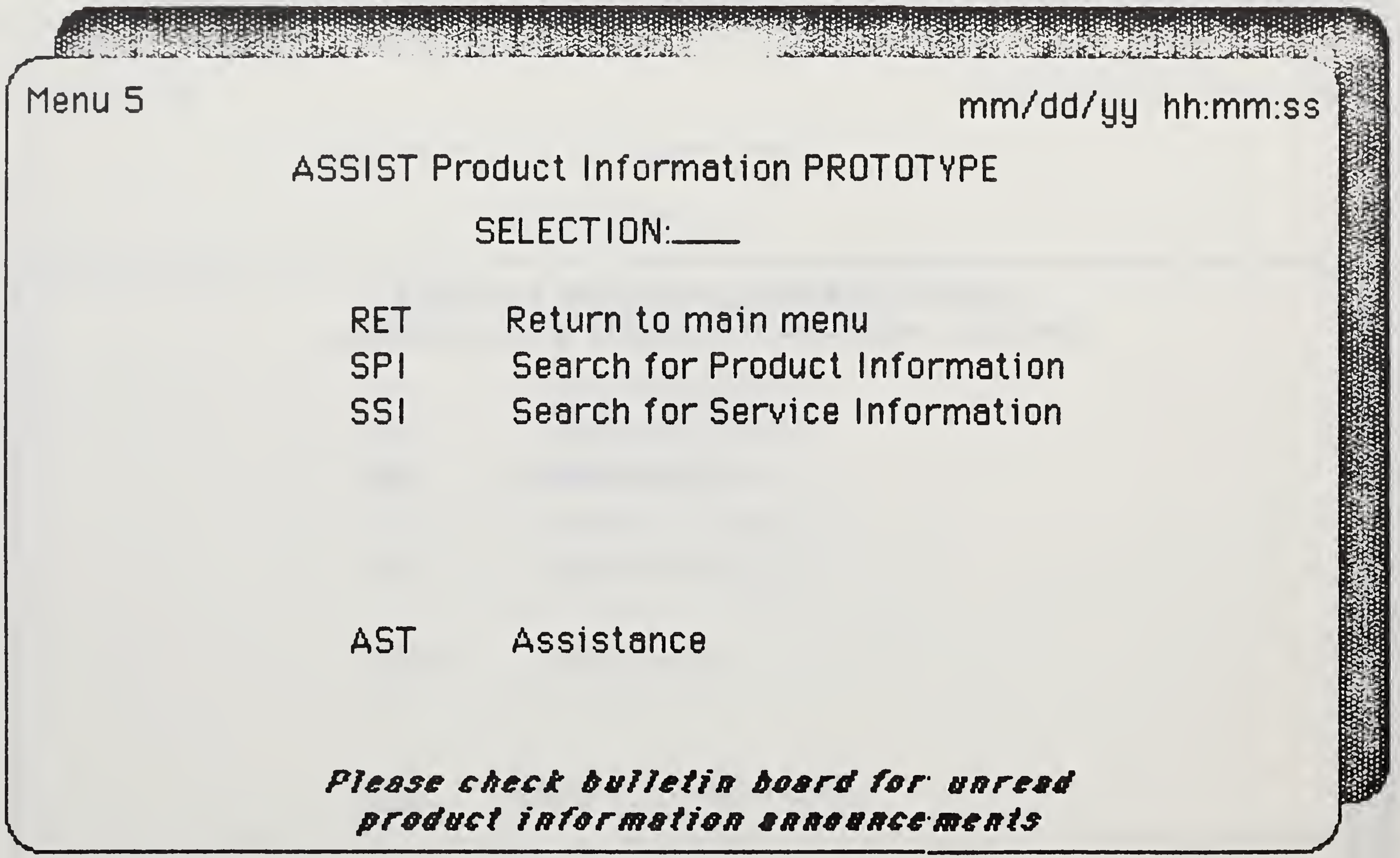

Menu 5
mm/dd/yy hh:mm:ss
ASSIST Product Information PROTOTYPE
SELECTION:____
RET Return to main menu
SPI Search for Product Information
SSI Search for Service Information
AST Assistance
Please check bulletin board for unread
product information announcements

Figure 15-15

Menu 6 mm/dd/yy hh:mm:ss

ASSIST Research in Progress PROTOTYPE

SELECTION:____

RET	Return to main menu
DOE	Connect to DOE RECON
AST	Assistance

Please check bulletin board for unread research in progress announcements

Figure 15-16

Menu 7 mm/dd/yy hh:mm:ss

ASSIST Tribology Bulletin Board PROTOTYPE

SELECTION:____

RET	Return to main menu
ANN	ATIS Announcements
NEW	Newsletters
ELM	Electronic Mail
NET	Network Access
TPP	Prototype Participants and Experts Directory
AST	Assistance

Please check your unread announcements

Figure 15-17

Automation Resource Requirements Checklist

	Biblio	Code	Num.	Cat.	Res.	News
I. Host Hardware						
A. Mini-Computer Class						
1. Virtual Machine						
2. 60 Concurrent Processes						
B. DASD Storage						
C. Magnetic Tape Backup						
D. Plug-in Hardware Expansion						
E. Communications						
F. High Speed Printer and Plotter						
II. Purchased Host Software						
A. FORTRAN, C, PASCAL, LISP compilers						
B. Assembly Language Interfaces						
C. Multi-Schema DBMS						
D. Graphics						
E. Electronic Mail						
F. Communications						
G. Word Processing						
H. Menu Systems/Screen Generators						
I. Report Writers						
J. Command Shell Script Generator						
III. User Interface						
A. IBM PC/XT Compatible Workstation						
1. Hardware						
a. Graphics						
b. Hard Disk						
c. Color Monitor						
d. 640K Memory						
e. Printer/Plotter						
f. Communications						
2. Software						
a. DBMS						
b. Graphics						
c. Spreadsheet						
d. Expert System Software						
e. Word Processing						
f. Virtual Terminal Emulator						
B. Dumb Terminal						
1. ASCII Compatible						
2. Modem						
3. Printer						
IV. Communications						
A. Dial-up/Call-out						
B. 15 lines						
C. 1200/9600 bps						
V. Personnel						
A. Tribologists						
B. System Users						
C. Information Specialists						
D. ADP Operations Staff						

Figure 15-18

CHAPTER 16

SYSTEM DEVELOPMENT TASKS

The following sections provide the task descriptions for the development tasks as discussed previously.

I. WORK STATEMENTS FOR SYSTEM MANAGEMENT TASKS

I-A. Present Workshop Results

Objective: The completed plan will be presented at a special session of the ASME/ASLE Joint Tribology Conference in Atlanta on October 10-11, 1985. Feedback from the attendees will be solicited by use of a questionnaire. Potential prototype users and contributors will be sought.

Task I-A-1: Preparation of Materials

- Edit numeric data base module from the August 1-2 meeting
- Develop as questionnaire for tribologists/design engineers
- Prepare presentation materials

Impact: It is important to have a well-thought-out plan for numeric data ready for presentation at the October meeting to ensure significant support by tribologists. A similar presentation must be made at a design engineers conference.

Deliverables: Edited return of the proposed technical plan
A questionnaire for tribologists/design engineers
Slides/viewgraphs for the presentation

Task I-A-2: Questionnaire Concerning Approaches and Proposed Data Capture Procedures

- Identify questions/issues
- Draw up the instrument
- Review and pre-test

Comments: The results of the questionnaire will validate the approach being taken and help identify users, applications, and contributors.

Deliverables: Questionnaire

Task I-A-3: Sign-up Prototype Users and Contributors

- Organization structure for sign-up process
- Materials

Impact: The objective is to recruit 40 tribologists and design engineers as users of the prototype. Appendix A contains a list of possible customers.

Deliverables: 40 prototype users

Responsible: Tribology Steering Committee

I-B. Organize Tribologist Support

Objective: To identify the tasks and assign their responsibility for completion to participating tribologists.

Task I-B-1: Finalize Data Sheets

- Review and evaluate proposed data sheets for various types of wear and related data. See Appendix B for sample sheets.
- Develop final data sheet forms

Impact: These data sheets will provide both the tools for data capture on this project and the standards for data capture for the production system.

Deliverables: Standard data sheets

Responsible: Tribology Steering Committee

Task I-B-2: Identify Authority Lists

- Identify authorities (allowed values, units conversion, etc.) for specific fields
- Establish lists of valid entries

Impact: Provide validation and data consistency feedback for data entry to ensure data integrity.

Deliverables: Authority lists

Responsible: Information specialists and Tribology Steering Committee

Task I-B-3: Expand Thesaurus from Bibliographic Module

- Identify numeric data specific terms
- Review and prepare thesaurus terms
- Integrate with bibliographic module thesaurus

Impact: This expansion of the thesaurus is necessary to ensure term standardization for consistent input and data retrieval.

Deliverables: Expanded thesaurus

Responsible: Information specialists and Tribology Steering Committee

Task I-B-4: Confirm Data Sources

- Select source for numeric data
- Produce indices
- Prioritize order for data capture

Impact: Five potential data sources have been identified, and the list needs expansion for completeness of data capture.

Deliverables: Prioritized list

Responsible: Tribologists

Task I-B-5: Copyright Checks and Infringement Avoidance

- Identify copyright liability

Impact: Copyright may be a significant issue in the extraction of numeric and design data from published materials.

Deliverables: Elimination of copyright infringement

Responsible: Tribology Steering Committee

II. WORK STATEMENTS FOR DESIGN TECHNIQUES TASKS

Figures 16-1 and 16-2 are sample questionnaire and form to be used in finding qualified design codes for inclusion.

II-A. Develop Component Selector Adviser

Objective: The objective of this task is the development of the component selector adviser. This is a small expert system which runs on an IBM PC and will assist the design engineer with the selection of an appropriate component for an engineering design.

Task II-A-1: Initiate Component Selector Adviser

- The information specialist will select and become familiar with the expert system tool.

Impact: Lays the foundation for the expert system builder (information specialist).

Deliverables: Expert system tool

Responsible: Information specialist

Task II-A-2: Establish Rule Formats

- The information specialist will generate the rule format for the tribologist.

Impact: Lays the foundation for the tribologist's rule generation.

Deliverables: Rule format

Responsible: Information specialist

Design Code Catalog Questionnaire

1. Code Name or Identifier - Enter the name of the code as it is commonly known; i.e. SHABERTH ______

2. Location/Personal Contact - Enter the location of the source code, name of person to contact and telephone number; i.e. COSMIC, Customer Service, (714) 555-1212 ______

3. Source Code and Documentation Medium - Enter the medium upon which the source code and documentation are available; i.e. source on magnetic tape, documentation on Wang Word Processor diskette Source Code ______ Documentation ______

4. Ownership/Cost - Identify the owner of the code, any special licensing arrangements and cost of acquiring the code; i.e. Public Domain, no license, $600 for tape copy ______

5. Host Machine/Language - Identify the host computer(s) on which the code runs and the programming language in which it is written; i.e. IBM 360/95, IBM 370/168, UNIVAC 1100 in FORTRAN 77 ______

6. User Interface - Describe how the user interacts with the code in its present form; i.e. punched cards submitted in a batch mode or entering parameters on-line via a terminal ______

7. Output Options - List how the results of the code's operation are presented to the user; i.e. paper printout, plotter display, terminal display, etc. ______

8. Tribo-Component/Area/Method - Describe what part of tribology uses this code; i.e. gears, bearings, lubrication, wear, etc. ______

9. Numeric Data Base(s) Used - List any external data bases that this code can use to extract data for its internal processing; i.e. Wear Handbook Database III.4 or NONE ______

10. Would this make a good code for the prototype (Y/N) ? ____ How good is it (0-10) ? ____

Please write a brief description of this code: ______

Figure 16-1

Tribological Component Characteristic Sources

	Materials	Geometry	Motion	Load	Environment	Mech. Data	Test	Use
General Name:								
Trade Name:								
Chemical Composition:								
CA Code/Registry Number:								
Surface Treatment:								
INPUT								
Curves								
Coefficients								
Index								
Life								
Function								
OUTPUT								
Curves								
Stat. Analysis								
Tables								
Rankings								

Figure 16-2

Task II-A-3: Develop Rules for Expert System of Tribological Component Selection

- The tribologist will develop the rules for the expert system which will aid in component selection.

Impact: The rules will form the foundation for the expert system.

Deliverables: Approximately 1,000 rules pertaining to tribological component selection

Responsible: Tribologist

Task II-A-4: Load Rules into the Prepackaged Expert System

- The information specialist will load the tribologist's rules, using the expert system tool.

Impact: Testing and iteration can now begin.

Deliverables: Initial self-contained expert system

Responsible: Information specialist

Task II-A-5: Iterate through Tribological Component Rules

- The information specialist and tribologist will work together to refine and/or augment the rule base for the component selection adviser expert system.

Impact: A small fine-tuned expert system is produced.

Deliverables: Prototype expert system for component selection.

Responsible: Information specialist and tribologist

Task II-A-6: Develop Guided Tour for Component Selection

- The tribologist will develop documentation for the component selection adviser regarding its use.

Impact: User-friendly documentation, developed from the user's point of view, will be provided.

Deliverables: Component selector adviser documentation

Responsible: Information specialist and tribologist

Task II-A-7: Provide Design Guidelines for Selected Components

- Select design articles from design engineering
- Obtain copyright permission
- Organize for load access by menus

Impact: Design engineering magazine, over the past 20 years, includes many design articles which should be made accessible.

Deliverables: On-line file of referenced design methods

Responsible: Tribologist and information specialist

II-B. Build Menu Shells

Objective: The main driver menus for the system and the menus for the design techniques module will be coded and tested.

Task II-B-1: Build Menu Shell

- The information specialist will build the menus for the front-end of the system and the design techniques module.

Impact: Front-end drivers will be completed.

Deliverables: Executable menus

Responsible: Information specialist

II-C. Integrate Existing Design Codes

Objective: The existing design codes will be integrated within one subsystem (module). Modifications to existing design codes will be required to provide a consistent front-end for the design codes and to provide execution flexibility (the removal of hard-coded data).

Task II-C-1: Plan Design Code's Selection

- A plan for the selection and integration of the design codes will be prepared.

Impact: The foundation for the design code incorporation into the design techniques module will be established.

Deliverables: Design code selection plan

Responsible: Information specialist and tribologist

Task II-C-2: Collect Documentation and Source Code

- The source code for the specified design codes will have to be collected along with all available documentation.

Impact: Enables the evaluation, modification, and integration of the design codes.

Deliverables: Design code source code and documentation on either magnetic tape or floppy disk

Responsible: Information specialist and tribologist

Task II-C-3: Analyze Selected Code for Usability

- The source codes for the collected design codes will be analyzed to determine the future modifications required for incorporation into the design techniques subsystem.

Impact: After analysis, the design codes can be modified.

Deliverables: Analyzed design codes

Responsible: Information specialist

Task II-C-4: Modify Codes as Required to Conform to Prototype Hardware

- The design codes will be modified to provide a consistent front-end and to access numeric data from the appropriate numeric data base.

Impact: Consistent design codes will exist.

Deliverables: Modified design codes

Responsible: Information specialist and tribologist

Task II-C-5: Develop Design Code Guided Tour

- The documentation on the use of the design codes will be prepared.

Impact: On-line documentation will be provided to assist with design code usage.

Deliverables: On-line documentation on design code usage

Responsible: Information specialist and tribologist

III. WORK STATEMENTS FOR BIBLIOGRAPHIC TASKS

III-A. Develop Gateway System

Objective: To provide a single point of access with associated database selection and switching capability based on user-specified vendor preferences.

Task III-A-1: Single Point Sign-on

- Create a set of screens for module options
- Implement telecommunications interface software for access to commercial vendors.

Impact: These are the basic access menus for access to all modules of the system.

Deliverables: Software for either PC or mini environment (to be decided) that performs above functions.

Responsible: Information scientists and operations

Task III-A-2: Bibliographic Services Switch

- Choose data bases/bibliographic services of concern.
- Create sets of screens to show description of chosen databases/ bibliographics services.
- Users can input names and access information for the services they wish to search on a routine basis.

Impact: This enables the user to scan some basic information for choosing any of the services/data bases and then call that service.

Deliverables: Software package with files of needed bibliographic data.

Responsible: Information scientists and operations

Task III-A-3: Database Selection Assistance

- Select two databases (EI Compendex and BAM Base Tribo)
- Compile information on the characteristics of the two databases
- Prepare associated Help screens for user assistance

Impact: This will provide the user with an easy look-up of the way the different databases treat subject or index terms in their respective files. It is also intended that the relative strengths and weaknesses of the databases would be indicated, especially in terms of general subject areas such as lubrication, gear wear, etc.

Deliverables: Set of screens which present the collected information

Responsible: Tribologists and information scientists

Task III-A-4: Choice of Outputs

- Check with database searchers on user options for formats for outputs including online/offline prints, floppy disks.
- Analyze and document any new output options required; investigate the copyright implications of any new output options.

Impact: This task will ensure that users have the opportunity to state clearly their requirements for new options at an early stage so that the feasibility of incorporating them into the system can be adequately evaluated.

Deliverables: A statement of the user output requirements

Responsible: Tribologists and information scientists

Task III-A-5: Parallel Searching (including merging of results with elimination of duplicates)

- Draw up specification of requirements for this task
- Develop user support module to provide user-transparent mapping of the profile for simultaneous query execution on relevant databases.
- Develop program to compare search results, eliminate duplicates, and merge the resulting set of hits.

Impact: The completion of this task is for the long range (more than one year). The prototype phase would probably only draw up a description of the requirements.

Deliverables: A detailed statement of the need based on only two or three bibliographic databases.

Responsible: Information scientists with consultation from tribologists

III-B. Create Glossary/Thesaurus

Objective: To compile a glossary of the terms used in tribology (with definitions where needed for clarification). This glossary/thesaurus would form the basis for mapping between the common word usage of tribologists and the indexing/classification schemes used by the commercial database vendors.

Task III-B-1: Compile Terms

- Tribologists will compile a list of terms used in the field.

Impact: There is a European Economic Community Directorate (EECD) glossary which can serve as the starting point for this work.

Deliverables: Hardcopy or softcopy glossary list.

Responsible: Tribologists

Task III-B-2: Review and Select Terms

- A panel of experts will review the list from Task III-B-1 and select the terms to be used in the prototype system.

Impact: Selection of terms with synonyms identified and associated definitions stated will be required to clarify the term usage within the field.

Deliverables: Hardcopy or softcopy list of terms, synonyms, and associated meanings.

Responsible: Tribologists

Task III-B-3: Create Thesaurus

- A thesaurus will be created showing synonymous and some narrower-term/ broader-term relationships between the list of terms. These terms must also be related to the indexing vocabulary used by any commercial vendors included in the prototype. This will conceptually be thought of as a term mapping. For example, the terms would have to be related to the classification scheme used by Base-Tribo.

Impact: This is not intended to be an exhaustive thesaurus of the tribological vocabulary. Its primary purpose is to provide a mapping between the uncontrolled vocabulary of everyday usage in tribology and the controlled vocabulary used in the commercial databases. The output of this task will also be used as one the inputs for Task III-A-3.

Deliverables: Hardcopy or softcopy list in a thesaurus format. Term mappings will be expressed via the "USE" relationship.

Responsible: Tribologists (primary) and information scientists as consultants

Task III-B-4: Create Machine-Readable Thesaurus

- A machine-readable thesaurus will be created that can be, at the minimum, accessed from the menus for browsing or searching.

Impact: The thesaurus will allow users to search bibliographic databases with more precision.

Deliverable: Thesaurus from Task III-B-3 incorporated in the search menus.

Responsible: Information scientists

III-C. Identification of Basic Information Sources in Tribology

Objective: To provide a user assistance guide to the field of tribology.

Task III-C-1: Update the "Guide to Sources of Information in Tribology"

- Perform the necessary library searches and associated evaluations to identify the changes and additions needed for the earlier report (Piternick, 1974).

Impact: The current publication is over 10 years old. After updating, it will serve as a valuable reference source.

Deliverable: Hardcopy publication

Responsible: Probably National Research Council of Canada

Task III-C-2: Convert to Machine-Readable Help File

- Organize the presentation of this publication to make it accessible as a M-R help file, probably as a tree organization (i.e., hierarchical structure).

Impact: When completed, this module would serve as a valuable user assistance tool as an online guide to the tribology literature.

Deliverables: Hardcopy structured presentation of sources from report that will then be installed as a set of subject-oriented menus that will identify the sources.

Responsible: Information scientists and tribologists

III-D. Develop Tutorial Files

Objective: To provide online tutorials in a small number of selected areas of tribology which will indirectly serve as a guide to the subject, content, and organization of the data in the Automated Tribology Information System.

Task III-D-1: Identify Five Subject Areas

- Identify the subject areas and the person(s) who will develop each topic.

Impact: If chosen appropriately, these tutorials could link to subjects in other modules of the system such as the Numeric Data and Design Codes.

Deliverables: A list of topics and authors

Responsible: NBS tribologists

Task III-D-2: Develop Tutorial Format

- A generalized format will be developed, based on the subjects and the anticipated access mode in the prototype.

Impact: A general format is important for ease of understanding by the users and the later addition of more topics.

Deliverables: Statement of format giving the areas to be discussed and their order.

Responsible: Tribologists and the authors

Task III-D-3: Prepare Tribology Tutorials

- Each author will prepare his tutorial materials in the agreed-upon format.

Impact: The prepared tutorial would be ready for use.

Deliverables: Hardcopy tutorials

Responsible: The authors

Task III-D-4: Convert/Install Tutorials in System

- Reformat the tutorials as needed to make them effective for presentation in an online format.
- Set up the menus and input the tutorials into the files needed for presentation.

Impact: The tutorials would provide users with better engineering tools.

Deliverables: A set of menus and files (tutorials)

Responsible: Information scientists, operations, and tribologists

III-E. **Pre-1970/72 Literature Database**

Objective: To ensure that users have minimum bibliographic access to the significant literature in tribology generated prior to 1970/72 and not currently indexed or referenced in existing online database sources.

Task III-E-1: Identify Items (approximately 5000)

- Perform approximate search and evaluation to identify the papers which qualify for inclusion.

Impact: There is a current estimate that on the order of 5000 significant technical papers or reports fall in the pre-1970/72 time period. A large number of these are already identified in reference lists.

Deliverables: Hardcopy list(s) of the items to be included. Minimum data for each item are the title, authors, publication title, data of publication, and volume/issue numbers for serials.

Responsible: Tribologists

Task III-E-2: Prepare Request for Quotation (RFQ)

- RFQ will be prepared to perform Task III-E-3.

Impact: The RFQ must include the normal areas required for government bid work if this is being funded by public funds.

Deliverables: RFQ

Responsible: Information scientists

Task III-E-3: Prepare Initial Machine-Readable Listing

- The listing(s) will be keyed into the appropriate machine-readable record format.
- The magnetic tape will be loaded and made accessible from one of the menus in browse mode in the minimum configuration.

Impact: Further processing of these data is possible.

Deliverable: A magnetic tape of the pre-1970/72 citations and online access to these data.

Responsible: Winner of the RFQ, information scientists, and operations

Task III-E-4: Perform Classification/Indexing (Long-Range Phase Two)

- Hardcopy full text of the references identified in Task III-E-1 would be collected.
- Classification/indexing of the articles is dependent on the online file to be used for presentation of the results.

Impact: The type of indexing to be done in this task will be highly dependent on the database producer to be used. This work would probably be done by the database producer.

Deliverable: Online access to the pre-1970/72 references via indexes, in addition to article title, author names, and publication title.

Responsible: Database producer, online vendor, and information scientists

Task III-E-5: Optical Disk of Full Text of Pre-1970/72 Literature

Impact: The successful completion of this task would ensure that copies of the full text of the basic papers in tribology prior to 1970/72 would be available to users in the field. Many of these papers are currently difficult to locate.

IV. WORK STATEMENTS FOR NUMERIC DATA BASE TASKS

Figures 16-3 and 16-4 are used to capture data about numeric data bases and their components for inclusion in the numeric data sets.

IV-A. Numeric Data Base Development

Objective: To ensure the inclusion of all published data. There appears to be no practical way to produce a critically evaluated data base.

Laboratory ______________________ Date __________ Test Series __________

Publication ID ______________________________________

		MATERIAL		3rd BODY COMPONENT		
		1	2	SOLID	GAS	LIQUID
MATERIALS	General Name					
	Trade Name					
	Function (A,L,I,C)					
	Chemical Composition					
	Physical Condition					
	CA Code/Registry #					
	Surface Treatment					
	Geometry					
	Roughness					
	Condition(process)					
	Supply Rate					
	Hardness					
	Density					
TEST		RUN 1		RUN 2	RUN 3	
	Mechanism					
	Use/Application					
	Load (N)					
	Normal Pressure (MPa)					
	Velocity (m/s)					
	Sliding Distance					
	Motion					
	Test Type					
	Contact Area					
	Contact Ratio					
	Temperature					
TRIBO DATA						
	Wear Vol1					
	Wear Vol2					
	Weight Loss1					
	Weight Loss2					
	Dimension Loss1					
	Dimension Loss2					
	Wear Rate					
	Wear Coefficient					
	Friction					
	Curves					
	Life					
	Surface Damage					
	Wear Debris (Type, Size)					
OTHER	Cleaning Methods					
	Special Test Features					

Figure 16-3

Laboratory ______________ Date ______________ Test Series ______________

Publication ID ______________

PRODUCT INFORMATION

	MATERIAL		MATERIAL CATEGORIZATION		
	1	2	KIND	APPLICATION	SPECIFICATION
Surface Name					
Composition					
Fabrication					
Heat Treatment					
Substrate Name					
Composition					
Fabrication					
Heat Treatment					
Sizes					
Speeds					
Speeds					
Sliding					
Rolling					
Temperature Limits					
Misalign. Constraints					
Mounting Consider.					
Lubricating/Cooling					
Torque Capacity					
Leakage Rate					
Dynamic Stability					
Damping					
Pressure Drop					
Availability					
Environ. Constraints					
Surface Finish					
Counter Material					
Compatibility					
Conform./Embed.					
Mechanical Prop.					
Elect. Prop.					
Thermal Prop.					
Finish					
Solvent Separators					
Water Separators					
Solid Separators					
Products Handled					
Bio Treatment					
Landfill					
Surface Impoundment					
Incineration					
Permits					
Refining					
Vendor					

Figure 16-4

Task IV-A-1: Develop Numeric Data Collection Instrument

Impact: This exercise develops the form for transferring bibliographic data to a numeric data base.

Deliverables: Comprehensive form for numeric data capture and identification

Responsible: Tribologists

Task IV-A-2: Validate Form and Define Literature Domain

Impact: This identifies the problems in using the previously defined form on the published tribological data.

Deliverables: Road map for numeric data base development

Responsible: Tribologists

Task IV-A-3: Data Input and Output Format Definition

Impact: This must be developed using a data base management tool with flexible report writer and graphics output.

Deliverables: Consistent units for input, storage, and output; criteria for a logical answer defined.

Responsible: Tribologist and information scientist

Task IV-A-4: Criteria and Reviewer Selection for Bibliographic Data Analysis

- 20 associate editors
- $100K total payments

Impact: The selection of the reviewers for this activity is critical since they will be the evaluators of the data for the numeric data base.

Deliverables: 4000 evaluated data points for the data base

Task IV-A-5: Prototype Data Selection

Impact: The previously identified associate editors will review the published information and select the numeric data base contents.

Deliverables: 4000 citations

Responsible: Tribologists

Task IV-A-6: Prototype Test and Evaluation

Impact: This is the first step in iterating through the numeric data base to test its applicability to the tribological tasks.

Deliverables: Enhancement plan

Responsible: Tribologist and information scientist

IV-B. Define Data Base Front-End

Objective: While all data base fields will be accessible, a user-friendly interface will need to be provided to facilitate efficient retrievals.

Impact: User reaction to the prototype must be judged on ease of use rather than simply the breadth of data coverage. Canned retrieval must be part of the system.

Deliverables: Menus with pre-packaged retrievals

Responsible: Information scientists and tribologists

IV-C. Tutorials

Objective: To ensure that users have assistance in understanding the availability and applicability of data for various tribology topics. There is a close association with the tutorial topics in the bibliographic module.

- Develop a generalized outline for the data section
- Prepare tutorials
- Integrate the tutorials

Impact: The tutorials could assist users in understanding how to apply the data in varying tribological circumstances.

Deliverables: Tutorials

Responsible: Tribologists and information scientists

IV-D. Data Organization

Objective: To ensure the inclusion of quality data sets.

Task IV-D-1: Data Preparation and Index Compilation

Impact: Five areas of data have been identified for which data sets, tables, and graphs need to be explicitly identified and an index prepared.

Deliverables: Identified data set

Responsible: Tribology Steering Committee and information scientists

Task IV-D-2 : Data Entry Program Preparation

- Prepare specifications
- Prepare routines
- Test and integrate

Impact: For consistent, accurate data entry, there needs to be available a data entry program for the hardware architecture selected.

Deliverables: Fully integrated data capture program

Responsible: Information scientists

Task IV-D-3: Data Entry/Digitization

- Determine data including plots and figures
- Assign data entry responsibility
- Enter the data

Deliverables: Correct data entered in the determined formats

Responsible: Data contributors

Task IV-D-4: Data Base Definition

- Select appropriate data base tool for numeric data
- Integrate into the system
- Define the data base for loading

Impact: This task is not a trivial effort and must be thoroughly coordinated with the other efforts under way.

Deliverables: Data base management system for numeric data

Responsible: Information scientists

Task IV-D-5: Data Base Load and Tie to Design Codes

- Load the data base with collected data
- Develop standard data transfer format to design codes
- Provide user access and transfer menus

Impact: This allows the user to load data into the data base management system and then extract them in a compatible format for design code usage.

Deliverables: Data base load mechanism and design code feeder.

Responsible: Information scientists

IV-E. Develop Numeric Data Module Assistance/Guided Tour

Objective: To ensure that users have an on-line assistance file including access to literature, consultants, experts, and other system users to assist in answering questions about the module use.

Impact: Adequate assistance screens must be included to assist designers in choosing the needed data for solving their problems.

Deliverables: Assistance files

Responsible: Tribologists and information scientists

V. WORK STATEMENTS OF RESEARCH IN PROGRESS MODULE TASKS

Task V-A: Review DOE Research in Progress (RIP) Database

- Check current file via searches for tribological work and compare results with the Peterson report on current DOE research projects.
- Prepare report of any missing projects.

Impact: Improve coverage of the DOE-RIP file

Deliverables: Hardcopy report

Responsible: NBS tribologists

Task V-B: Addition of Government-Funded Projects

- From the Task V-A work, provide to DOE-OSTI recommendations for any additional government projects to be added to the RECON RIP file.
- Projects are added by DOE-OSTI.

Impact: Up-to-date compilation of current DOE research projects in tribology. DOE-OSTI is currently producing a bimonthly current awareness bulletin. This work will ensure the back-file is complete.

Deliverables: Complete tribology coverage in DOE ITIS RIP file.

Responsible: DOE-OSTI

Task V-C: Industrial RIP Coverage

- The Tribological Steering Committee would identify R&D projects and sponsoring companies or universities which should be included in the DOE RIP file (subject to DOE approval, see Task V-E).
- The current DOE Form 538 for collecting DOE-funded project data will be amended and modified as needed to make it appropriate for collecting data on nongovernment-sponsored R&D work in the tribology area.
- The Tribo-Steering Committee will develop a mechanism that can be used in an ongoing basis to collect data on nongovernment-sponsored R&D work in the tribology area. They would also collect initial data using the modified Form 538 to cover current project work.
- If DOE-OSTI has agreed to include these data in the RIP file, the completed forms will be submitted for inclusion in the file.

Impact: Broaden the coverage of DOE RIP to include industrially funded (nongovernment) projects of interest to tribology. Since the DOE RIP file is supplied to Dialog (and any interested commercial online vendors) in Fed RIP via NTIS, this is the simplest way to make these data available to tribologists.

Deliverables: An initial list of project work to be added to DOE RIP, followed by updates on a regular basis.

Responsible: Tribologists and DOE-OSTI

Task V-D: Tribology Thesaurus for DOE

- Submit the thesaurus developed in the bibliographic module to DOE-OSTI for addition, in whole or part, to the thesaurus currently being used by DOE for indexing of projects placed in the RIP file. It may be necessary to modify the thesaurus developed in the bibliographic module to fit the indexing schema used by DOE.
- A mapping of common tribological terms to those used in the DOE-RIP file would be developed if a definite need for this was demonstrated.

Impact: The primary goal is the improvement of the indexing of the tribological literature (research-in-progress) that is being included in the DOE-RIP file.

Deliverables: Hardcopy or softcopy listing of thesaurus terms.

Responsible: Information scientists, DOE, and tribologists in consulting role.

Task V-E: Approvals to Use DOE-ITIS

- Prepare a statement of the requirements that will exist if the DOE RIP file is used as the mechanism to provide a RIP file for the area of tribological research. This statement should discuss any questions of access to DOE files by personnel not associated with DOE projects and the tradeoffs of access to the DOE RIP file versus the RIP supplied to any commercial vendors. The different user classes (perhaps in terms of organizational affiliations) should be defined and the access options for each given. There are two approvals to be decided. First, will DOE-OSTI include nongovernmental research in their RIP file, and, second, will they allow access to the DOE version of this file to personnel not working on DOE projects.
- Seek a DOE-OSTI policy decision.

Impact: Both approvals provide a simple means to fulfill the requirement of providing a RIP file for the tribological R&D area. If the inclusion of nongovernmental projects is approved but access is not, then the basic data will still be available via Dialog. At least two levels of access are possible. Most general is access to all files on DOE ITIS. Next would be access to only the RIP file.

Deliverables: Policy decisions

Responsible: Tribology Steering Committee and DOE-OSTI

Task V-F: User Assistance Manual

- Modify the existing ITIS RIP manual to highlight the tribologically related features. Depending on the decisions in Task V-E, it may be necessary also to suggest changes to the user manuals of any commercial vendors using the DOE RIP file.

Impact: To have available a user manual specifically tailored to the tribological module of the RIP file in order to maximize its usefulness to tribologists. It may be useful to have different formats of this manual such as printed, online, and videotape.

Deliverables: Initially a hardcopy manual

Responsible: Tribologists and information scientists

Task V-G: Standard RIP Search Profiles

- Define tribological areas of interest
- Prepare search profiles for these selected areas
- Test the search profiles on DOE RIP file
- Submit the search profiles to DOE-OSTI for use as current awareness or SDI searches

Impact: These profiles could provide a very simple means for a majority of tribologists to maintain an awareness of the work being done in their areas of interest without having to bother with running their own searches.

Deliverables: Hardcopy search profiles submitted to DOE-OSTI

Responsible: Tribologists

VI. WORK STATEMENTS FOR NEWSLETTER MODULE TASKS

Task VI-A: Editor Develops Detail Plan for Implementation

- Coordinate efforts of assistant editors
- Coordinate new system entries
  - Bibliography - Kennedy
  - Design Techniques - Sibley
  - Numerical - Ruff, Klaus
  - Research in Progress - Peterson
  - Product Directory - Fein

Impact: Provides the road map for the newsletter function

Deliverables: Plan for newsletter implementation

Responsible: Tribologists

Task VI-B: Plan and Implement the Bulletin Board System

- Plan the entire bulletin board system
- Emphasize the newsletter
- Provide the links for electronic publishing and typesetting

Impact: This provides the automated framework for installing the newsletter in an electronic mail system.

Deliverables: On-line system of mail, newsletters, and users' access

Responsible: Tribologists and information scientists

Task VI-C: Develop and Implement Continuing System Management

- Register users
- Provide access controls to selected newsletter sections
- Assign system manager

Impact: This task lays out the ongoing support mechanism for the bulletin board module.

Deliverables: Management plan and system manager

Responsible: Tribologists

VII. WORK STATEMENTS FOR PRODUCT DIRECTORY TASKS

VII-A. Resolve Legality Concerns

Objective: The questions regarding liabilities associated with the product data base have to be resolved to support the product data base feasibility and content requirements.

Impact: Issues such as advertisement, vendor data selection, vendor participation (fees paid by the vendor), and prototype data selection are resolved and approved by legal counsel.

Deliverables: Product data base approval

Responsible: Tribologists and lawyers

VII-B. Prepare/Submit Product Directory Advertisement

Objective: The advertisement for the solicitation of vendor product data will be prepared by the tribologist in conjunction with a marketing specialist. The advertisement will be sent to the printers and then to the appropriate journals.

Comment: The prototype data for the products to be contained within the products directory data base will be obtained through this mechanism.

Deliverables: Product data base advertisement

Responsible: Tribologists, marketing specialist, and printers

VII-C. Contact Businesses Regarding Product Data

Objective: Certain businesses will be contacted directly to encourage product data inclusion which will be necessary to supplement the other ASSIST modules.

Comment: Direct contact will encourage prototype participation.

Deliverables: Contacts with relevant businesses

Responsible: Tribologists

VII-D. Define Data Base Front-End

Objective: The user-friendly front-end for the products directory will be designed and built. This will include a menu and an interactive query language for keyword searching.

Impact: The product directory information can be accessed using multiple keywords as a search criterion.

Deliverables: Menus and an interactive query language.

VII-E. Arrival of Vendor Data

Objective: The vendor data will be received at the prototype computer center and then loaded onto the computer system. Unreadable tapes or disks will have to be returned to the vendor for a replacement tape.

Impact: The vendor data will then be online for entry into the data base.

Deliverables: Online vendor data

Responsible: Information specialist

VII-F. Data Base Definition and Preparation of Support Procedures

Objective: The products directory data base will be defined by the information specialists, and necessary support procedures will be coded and tested. Validation procedures will also have to be defined.

Impact: The products directory data base will then be available for data base loading.

Deliverables: Defined data base and support procedures

Responsible: Information specialist

VII-G. Convert ASLE Data

Objective: The ASLE consultants data base will be converted to the services record type of the Automated Tribology Information System. The services record includes name, location, finishing, phone number, and a comments field for tribologically related information.

Impact: Existing data will be converted to the ASSIST format.

Deliverables: ASLE converted data

Responsible: Information specialists

VII-H. Load Data Base

Objective: The data base will be loaded with the vendor-supplied data and the ASLE consultants' data.

Impact: The data base will then be available for testing.

VII-I. Develop the Products Directory Assistance/Guided Tour

Objective: Tutorials to aid the user in the use of the product directory will be prepared by the tribologists and integrated into the Automated Tribology Information System by the information specialist.

Impact: Retrieval of relevant information will be a by-product of the availability of online tutorials.

Deliverables: Online tutorials

Responsible: Information specialist and tribologist

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APPENDIX A

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APPENDIX B

WORKSHOP AGENDA

Planning Workshop Program
on
Computerized Tribology Information System Development
by
Research Committee on Tribology
American Society of Mechanical Engineers
for
U.S. Department of Energy ECUT Tribology Project
at
National Bureau of Standards
Gaithersburg, Maryland USA

15 July - 9 August 1985

Monday 15 July - Plenary Session
Lecture Room D, Administration Building

8:30 am	Registration
9:00 am	Welcome by Dr. Lyle Schwartz, Director, NBS Center for Materials Science
9:10 am	Engineering Overview by Prof. Ali Seireg, University of Wisconsin, ASME Senior Vice President for Engineering and Chairman, Council on Engineering
9:30 am	ASME/NSF Projects on Computerized Mechanical Design Methodologies by Prof. Karl Reid, Oklahoma State University, ASME Vice President, Board on Communications
10:00 am	Coffee break
10:20 am	Tribology Keynote Address by Dr. Manfred Kaminsky, Argonne National Laboratory, Manager of DOE/ECUT Tribology Project
10:50 am	Workshop Goals and Organization of Working Tasks by Lewis Sibley, Tribology Consultants, Inc., ASME Tribology Workshop Chairman
11:10 am	Review of Computerized Information System Development by Dr. John Rumble, NBS Office of Standard Reference Data
Noon	Lunch

1:00 pm Computerized Information Systems in Industry by Dr. Walter Grattidge, Knowledge Systems, Inc.

1:30 pm Status of Bibliographic Data Bases in Tribology by Prof. Francis Kennedy, Dartmouth College

2:00 pm The German Tribology Data Base TRIBO by Harald Tischer, Rheology and Tribology Documentation Service, BAM

2:30 pm Adapting Existing Design Model Codes for Wide Usage by a selected staff member from the NBS Office of Standard Reference Data

3:00 pm Coffee break

3:20 pm Methodology of Material Phase Diagram Data Bases by Joanne Murray, NBS Metallurgy Division

3:50 pm Review of Corrosion Data Base Development by David Clausen, NBS/NACE Research Associate

4:20 pm Fatigue Data Bases in Industry by Susan Foss, Engineering Mechanics Department, Deere and Company

4:50 pm Wrap-up and Charge to Working Task Groups by Lewis Sibley, Tribology Consultants, Inc., ASME Tribology Workshop Chairman

Tuesday 16 July through Friday 19 July - Bibliographic Task
Administration Building (except Thursday morning in Materials Building)

Tuesday 16 July through Friday 19 July - Design Techniques Task
Administration Building

Monday 22 July through Wednesday 24 July and **Monday 29 July through Wednesday 31 July** - Numeric Data Base Task
Administration Building (except on Tuesday and Wednesday 23 and 24 July in Materials Building)

Thursday 25 July and Friday 26 July - Research in Progress Task
Materials Building on Thursday, and Administration Building on Friday

Friday 26 July, and Thursday and Friday 8 and 9 August, if needed
Newsletters Task, Administration Building

Monday 29 July through Wednesday 31 July, and **Monday 5 August through** Wednesday 7 August - Product Directory Task
in Administration Building

Thursday 1 August and Friday 2 August - Coordination Wrap-up
in Administration Building

Meeting of all Task Chairmen to coordinate planning efforts and organize final report inputs for each task area.

Work Statement

The Research Committee on Tribology of the American Society of Mechanical Engineers will conduct a planning study to define a computerized tribology information system. This planning study will consist of the following tasks:

1. Task groups of selected experienced tribologists will be organized in the following subject areas: bibliographic information, design techniques, numeric data, product directory, research in progress, and newsletters.

2. A study will be carried out in conjunction with information specialists at the National Bureau of Standards to prepare a working plan for the development of a computerized tribology information system.

3. The working plan will address each subject area. It will define what information should be included, its format, how it should be stored and accessed, when it should be updated, the cost for establishing and operating each database, and its objectives based upon user needs.

4. A final report will be prepared which summarizes the results of the study and recommends a course of action for the preparation and operation of such a system.

Background

Technical information on the tribological characteristics of materials and mechanical system designs (having to do with friction, lubrication and wear of sliding/rolling contacting surfaces such as those in bearings, gears, seals, and other components) is being generated at a prolific rate. It has been stated that half the scientific research done in the U.S. since its founding in the eighteenth century has been done in the last eight years. Since tribology can be applied to any machine or device having moving parts with a variety of surfaces and environments, tribological data are found in a wide range of industries and publications, and they involve diverse technologies and academic disciplines.

Recent advances in the techniques for development of computerized knowledge bases and expert systems may offer some hope for the cost-effective organization and utilization of both currently available and future generated tribology information. The recent meetings of the Industrial Research Institute (IRI) Conference on Tribology and the Canadian Associate Committee on Tribology (ACOT) both recommended as the highest priority the development of a computerized tribology information system. However, there are many

questions concerning such a proposed system, viz: its objectives, format, type of available information, cost/benefit ratios of including special kinds of information, the long-term method of operation and maintenance, and feasibility.

What is needed at this point is a planning study which clearly defines the desired system requirements and the ultimate cost of developing and operating an effective system. For this purpose, therefore, the ASME Research Committee on Tribology, with partial support from DOE, will conduct an assessment of existing information system technology and develop a plan for the orderly step-by-step cost-effective implementation of an intelligent, user-oriented, consolidated, computerized tribology information service over the next three to five years for the broad engineering community. This planning study will include not only ASME but also will be coordinated with other technical societies and organizations such as ACOT, AFBMA, AGMA, API, ASLE, ASM, ASTM, AVS, BAM, CISTI, CRC, IRI, NLGI, SAE, and SME.

Approach

The development of a meaningful plan for a tribology information system will require intense interaction between

- experienced tribologists representing each of the several disciplines involved, and

- information specialists having in-depth familiarity with existing databases and information systems and computerized techniques that might be useful for cost-effective tribological technology transfer.

Membership in the ASME Research Committee on Tribology (RCT) is intentionally aimed at a balanced composition representing the various disciplines in tribology from industry, government, and academia. Each RCT member maintains state-of-the-art surveillance of the tribological technology within these disciplines, including a recent survey of current bibliographic databases in tribology to be published in a forthcoming issue of ASME's Journal of Tribology. ASME has an abiding interest in the development of computerized database systems for the mechanical engineering community which is responsible for the technology of machine design, operation, and maintenance, where tribology information is needed most critically.

The National Bureau of Standards (NBS) is assigned the national responsibility for measurements technology and data systems of all kinds including tribology. In recent years, NBS has worked in close coordination with the extensive proprietary material databases used in industry, such as those at General Electric Company and at Deere and Company. NBS specialists have planned and implemented computerized databases for the fatigue, corrosion, crystallographic, and thermodynamic properties of materials, including specialized data verification and evaluation codes. Some of these are being implemented in coordination with the cognizant technical societies, viz.: ASME for fatigue, NACE for corrosion, and ASM for the phase stability and other properties of metals and alloys.

The ASM data system involves both mainframe computer systems and data disks for personal computers (PC's). ASM staff and outside contractors provide maintenance and updating services. The ASME mechanical fatigue database called DATAX was designed by NBS for PC systems. And the National Association of Corrosion Engineers (NACE) uses a NACE/NBS corrosion data system for PC's that has been operating for over a year now with hard-copy call-up capabilities.

The approach for planning a cost-effective tribology information system, therefore, is to hold an intensive four-week workshop at NBS with representative members of RCT and other experts in the various tribological disciplines interacting with the information scientists at NBS. This workshop is organized around the following six tasks designed to provide the complex transmittal of tribological data and design information to the engineering community most efficiently and timely, using the latest available computerized information science methods

- bibliographic information
- design techniques
- numeric data
- product directory
- research in progress
- newsletters

Task groups of selected experienced tribologists organized by designated Task Chairmen will interact with a group of information scientists organized by the NBS Office of Standard Reference Data during an intensive four-week workshop at NBS to work out and document a detailed plan for the development of specific systems and actions in each of these task areas. Costs will be estimated for the implementation, operation, and updating of each recommended system. The objective is to decide what is available and to recommend the most cost-effective approach.

After completion of the four-week NBS workshop, each of the task group chairmen will prepare their input to a comprehensive report containing a detailed plan for implementation of the tribology information system for their task, including a concise statement of the objective from the terminal user's viewpoint. This report will detail the recommended implementation method and cost as well as the means for updating and validating the system as new information becomes available.

The workshop report will be the first comprehensive long-range plan developed for tribology data and information systems. It will have features of direct interest to DOE and will also offer other organizations and individuals valuable information for their tribology-related work.

<u>Coordination with Other Organizations</u>

The ASME/NBS workshop will begin with a keynote address by Dr. Manfred Kaminsky of Argonne National Laboratory, the Manager of the DOE/ECUT Tribology Project. The above task groups include tribologists and others who

will coordinate this ASME/NBS planning effort with other technical societies and organizations. The following is a list of persons designated for coordination with each organization:

ACOT	Prof. John Molgaard, Memorial Univ. of Newfoundland
AFBMA	Mr. Anderson, Consulting Engineer
AGMA	Prof. Cheng of Northwestern
API	Prof. Klaus of Penn State
ASLE	Dr. Stephen Hsu of NBS
ASM	Dr. Peter Blau of NBS
ASTM	Dr. Ruff of NBS
AVS	Dr. Kaminsky of DOE Argonne
BAM	Mr. Tischer of Tribology Index
CISTI	Dr. Metcalfe of Atomic Energy of Canada
CRC	Mr. Sibley of Tribology Consultants
IRI	Dr. Donald F. Hays of General Motors
NLGI	Dr. Fein of Richard S. Fein Associates
SAE	Mr. Peterson of Wear Sciences
SME	Prof. S. Ramalingam of the University of Minnesota

APPENDIX C

DESCRIPTION OF DESIGN CODES

THE JBMTI MICROPROGRAM

Journal bearings are present in nearly all rotating machinery, and they play a vital role in system performance. The engineer needs bearing data in the course of designing and evaluating his equipment, and bearing coefficients are needed to evaluate a system's overall rotordynamic characteristics. Also, personnel in charge of plant facilities must have access to bearing data in order not to exceed operational limits like minimum film thickness, temperatures, vibration, etc. The JBMTI Program attends to these needs by generating an output tailored specifically to equipment design and performance calculations of operating machinery.

In the simplicity of both its format and execution, the JBMTI Program is a powerful and flexible engineering tool requiring the minimum of preparation and operating at practically no cost. The code contains the following features:

- Input consists of practical dimensional parameters such as diameter, rpm, load, etc., with the output printed in convenient dimensional forms.

- The program has two modes of operation: one, when shaft position is given, it calculates the corresponding bearing performance; or, when load and load direction are given, the program will execute an internal iteration to arrive at shaft position and the corresponding bearing performance.

- The program treats a bearing having up to six pads; any degree of preload (elliptical, 3-lobe, etc.); in any arbitrary load angle.

- The program employs a consistent thermal approach by iterating for the bulk or average film temperature based on the corresponding power loss and side leakage.

- The program has the temperature-viscosity properties of several standard SAE oils built in and permits the introduction of other fluids of arbitrary viscosity-temperature dependence.

- Aside from the usual performance items such as horsepower, flow, minimum film thickness, etc., the program calculates the bearing's eight spring and damping coefficients required to evaluate rotor dynamic performance.

- Both input and output are displayed on the PC screen and execution time is of the order of fractions of a minute.

JBMTI can be used on an IBM PC or compatible system with at least a 192K-byte memory.

EHDSTAR

DOCUMENTATION SOURCE: Tribology Consultants, Inc., 504 Foxwood Lane, Paoli, PA 19301

LOCATION/CONTACT: Lewis B. Sibley, Tribology Consultants, Inc.

ACCESS TO SOURCE CODE: Yes, on a proprietary basis

OWNERSHIP/COST: TCI/NC for demo

TRIBO COMPONENT/AREA/METHOD: Oil or grease lubricated ball bearing/partial elastohydrodynamic/analytical

OUTPUT OPTIONS: Screen, printed hard copy, diskette file

INPUT FORMATS: Interactive screen

USER INTERFACE: Video screen

NUMERIC DATABASES NEEDED: Standard bearing dimensions, bearing material, and oil properties default; user may override with any special bearing geometry, bearing material, or lubricant properties: Young's modulus, Poisson's ratio, viscosity at 100 and 210 F, specific gravity, pressure viscosity index, air/oil surface tension

GOODNESS FACTOR: 9

PROTOTYPE USE: Yes

ABSTRACT: This program computes the quasidynamic balance of forces and velocities of the balls in either a deep groove or angular contact ball bearing with full consideration of the ball centrifugal force and ball/race contact tractions. Then the dimensions of the ball/race contacts are computed and the thickness of the elastohydrodynamic lubricant film as well as the distance of the air/oil meniscus from the front of the contact using partial EHD starvation theory. Lastly, the bearing material L10 fatigue life is computed, accounting for both the material life factor and a life factor based on the ratio of the EHD lubricant film thickness to the composite roughness of the ball/race contact surfaces (specific thickness ratio).

HOST MACHINE/LANGUAGE: CP/M or MS DOS

Brief Description of Computer Code EHDSTAR

The difference between EHDSTAR and the conventional way of calculating the elastohydrodynamic (EHD) lubricant film thickness in a ball bearing is that EHDSTAR computes both the generation of the EHD lubricant film in the contacts and the flow of the oil in and around the tracks in the bearing. In this way, the effects of the partial starvation of the contacts, which is very important in many applications, can be fully accounted for. This is especially true for grease lubricated ball bearings operating at high speeds where the only oil available to the contacts must be supplied from the oil bleeding out of the greasepacks at the edges of the tracks formed by proper channeling of the grease. These partial EHD starvation effects also play a critical role in any other type of minimally lubricated ball bearing, such as the evaporative lubricant plated bearings used in instruments and space satellite applications.

In Table I, for example, the results of running a 35 mm bore angular contact ball bearing at high speed with only a plated on supply of SAE 30 lubricant having moderately high viscosity at the operating temperature of 120 F show that the meniscus of oil forms in front of each ball very close to the contact edge (at a distance of only about half a thousandth of an inch). A very thin film of lubricant is left on the bearing tracks behind each ball/race contact. If no additional lubricant replenishes this film in the track before the next ball rolls over it, there will not be enough film thickness in the track in front of this next contact to completely fill the contact region, thus causing reduced film thickness and possible lubrication distress. Note that the EHD lubricant film thickness in this example is reduced to only six percent (oil starvation film reduction ratio = .06) of that which would have been generated if there had been an infinite supply of oil to the contacts. Nevertheless, the film thickness is still about one-half of the composite roughness of the ball/race contact surfaces (EHD specific oil film thickness ratio = .48), which results in significantly reduced fatigue life and the possibility of lubrication distress unless an oil is used with appropriate boundary lubrication additives. Satisfactory bearing material fatigue life is achieved in this case only by running the bearing under low applied loads.

This computer output illustrates the visibility that such analyses can provide for the complex interacting processes acting in bearing systems. Other computer codes are also available to assure the level of reliability needed in modern machinery bearing systems.

Lewis B. Sibley
Tribology Consultants, Inc.

HIPRESSA

DOCUMENTATION SOURCE:	Available from author. Theoretical details are published paper.
LOCATION/CONTACT:	Coda H.T. Pan/same 2200 N. Central Rd., 10K Fort Lee, NJ 07024 (201) 944-3214
ACCESS TO SOURCE CODE:	Yes, third party distribution by permission.
OWNERSHIP/COST:	Coda H.T. Pan /NC for Prototype Phase
TRIBO-COMPONENT/AREA/METHOD:	Gas lubricated journal bearing/Hydrodynamic Brg/ Analytical
OUTPUT OPTIONS:	Printer, diskette
INPUT FORMATS:	Interactive input or perforated file.
USER INTERFACE:	?
NUMERIC DATA BASE(S) NEEDED:	Standard air properties are default, user may override with properties of any other gas: ratio of sp-hts., universal gas constant, viscosity.
GOODNESS FACTOR (0-10):	9, well tested.
PROTOTYPE USE (Y/N):	Yes.

ABSTRACT:

HIPRESSA treats the externally pressurized air-lubricated journal bearing with a single row of feed-holes (inherently compensated restrictors). It sizes feed-holes to avoid exit choking and treats the feed-holes as discrete entities with allowance for local Reynolds number effects.

HOST MACHINE/LANGUAGE:	IBM PC/Microsoft Basica

SEALS

DOCUMENTATION SOURCE: Gordon Buck, Jr., 5801 Parkhaven Drive, Baton Rouge, LA 70816. Tel: (504) 293-6581.

LOCATION/CONTACT: Gordon Buck, Jr.

ACCESS TO SOURCE CODE: Floppy Disk

OWNERSHIP/COST: Gordon Buck, Jr.

TRIBO-COMPONENT/AREA/METHOD: Seals (Mechanical face)

OUTPUT OPTIONS: Screen or printed hard copy. Balance ratio, diameter required for specified balance, heat generation, coolant rate required, PV factor, dynamic stability, thermal shock parameter, and temperature distributions.

INPUT FORMATS: Menu driven.

NUMERIC DATA BASES NEEDED: Properties of materials and fluids.

GOODNESS FACTOR: 6

PROTOTYPE USE: Yes.

ABSTRACT: Three dimensionless parameters - stability factor, liquid design factor and strength design factor are based on mechanical seal theory. Outputs include balance ratio, diameter required for specified balance, heat generation, coolant rate required, PV factor, dynamic stability, thermal shock parameter, and temperature distributions.

HOST MACHINE/LANGUAGE: HP 85, 86, 9816. Basic.

MECHANICAL SEALS PAC

A Program for Mechanical Seal Calculations

1 Introduction

In spite of recent advancements in mechanical sealing technology, seal failures are a common cause of equipment repair. Many seals are actually misapplied because the calculations necessary to analyze seals can be quite tedious. In some cases, the analytical procedure is not generally known. Mechanical Seals Pac can be used to analyze seals and services so that a better application occurs.

Mechanical Seals Pac (SEALS) is a versatile program for machinery engineers to use on the Hewlett-Packard computers. To use SEALS on the HP-9816, at least 256K of RAM and a printer are required. Graphs are "dumped" to the printer, so pen type plotters are not required or used. Similarly, special ROM's are not necessary. Only one disk drive is used. In other words, this is a program designed for the "basic" HP-9816 system.

Although the system requirements are small, SEALS is a powerful program. A summary of these capabilities is listed below

1. The geometric balance ratio can be calculated as a function of the face diameters or diameters can be calculated for a specified balance ratio.

2. Heat generation and "PV" parameter can be calculated.

3. Leakage can be calculated as a function of seal face separation.

4. Flow rates for API flushing plans 11, 13, and 31 can be determined as a function of pressure.

5. The maximum pressure which can be sealed with a distorted face can be determined for a given seal.

6. Temperature distribution can be calculated for a simple rectangular solid geometry.

7. The combined performance of a rotating and stationary element can be analyzed assuming a simple rectangular solid. If the "shape factors" are known, this analysis gives a good estimate of the true performance.

In addition, other factors such as thermal shock parameter, temperature rise in the flush, convective heat transfer coefficient, and frictional horsepower can be determined. All of these calculations are easily accomplished with SEALS.

2 The Scope of Mechanical Seals Pac

The calculations performed in SEALS can be grouped into two categories. In the first category are the conventional and simple calculations such as balance ratio, PV factor, and heat load. While these equations are well known, SEALS makes using them easy and consistent while also providing a nice printed output. The second category consists of the more complex calculations such as temperature distribution and convective heat transfer coefficient. Other calculations, such as stability and flush rates, might be placed in either category, depending on the experience of the user.

In using SEALS, you will notice that neither input nor calculated values are passed between calculations. For example, you might determine the convective film coefficient and still be prompted to enter a value for it in the next calculation. This has been done intentionally so that you can investigate the effects of variations in these parameters.

SHABERTH-COMPUTER PROGRAM FOR CALCULATION OF THERMAL PERFORMANCE OF A SHAFT BEARING SYSTEM
(SKF INDUSTRIES, INC.)

This computer program, called SHABERTH, was developed to predict the steady state and transient thermal performance of a multi-bearing shaft system operating with either wet or dry friction. SHABERTH is a design analysis tool with which the thermal performance characteristics of a shaft bearing system can be determined. SHABERTH calculated the loads, torques, temperatures, and fatigue lives for ball and/or roller bearings on a single shaft. The comprehensive nature of this program allows for the study of many causes of bearing instability. The program also allows for an analysis of the system reaction to the termination of lubricant supply to the bearings and other lubricated mechanical elements. SHABERTH should prove to be a valuable tool in the design and analysis of shaft bearing systems.

The SHABERTH program is structured with four nested calculation schemes. The thermal scheme performs steady state and transient temperature calculations which predict system temperatures for a given operating state. The bearing dimensional equilibrium scheme uses the bearing temperatures, predicted by the temperature mapping subprograms, and the rolling element raceway load distribution, predicted by the bearing subprogram, to calculate bearing diametral clearance for a given operating state. The shaft-bearing system load equilibrium scheme calculates bearing inner ring positions relative to the respective outer rings such that the external loading applied to the shaft is brought into equilibrium by the rolling element loads which develop at each bearing inner ring for a given operating state. The bearing rolling element and cage load equilibrium scheme calculates the rolling element and cage equilibrium positions and rotational speeds based on the relative inner-outer ring positions, inertia effects, and friction conditions. The ball bearing subprograms in the current SHABERTH program have several model enhancements over similar programs.

These enhancements include an elastohydrodynamic (EHD) film thickness model that accounts for thermal heating in the contact area and lubricant film starvation; a new model for traction combined with an asperity load sharing model; a model for the hydrodynamic rolling and shear forces in the inlet zone of lubricated contacts, which accounts for the degree of lubricant film starvation; a modeling of the normal and friction forces between a ball and a cage pocket, which accounts for the transition between the hydrodynamic and elastohydrodynamic regimes of lubrication; and a model of the effect on fatigue life of the ratio of the EHD plateau film thickness to the composite surface roughness.

SHABERTH is intended to be as general as possible. The models in SHABERTH allow for the complete mathematical simulation of real physical systems. Systems are limited to a maximum of five bearings supporting the shaft, a maximum of 30 rolling elements per bearing, and a maximum of 100 temperature nodes. The SHABERTH program structure is modular and has been designed to permit refinement and replacement of various component models as the need and opportunities develop.

This program is written in FORTRAN IV and has been implemented on a UNIVAC 1100 series computer with a central memory requirement of approximately 86K of 36 bit words. SHABERTH was developed in 1976.

SHABERTH is available by lease for a period of ten (10) years to domestic lessees. The leased program product includes the source code and one copy of the supporting documentation. Additional copies of the documentation may be purchased separately at any time.

LANGUAGE: FORTRAN IV

MACHINE REQUIREMENTS: UNIVAC 1100 SERIES

PROGRAM SIZE: Approximately 12,680 Source Statements

DISTRIBUTION MEDIA: 9-Track 800 BPI Univac FURPUR Format Magnetic Tape

PROGRAM NUMBER: LEW-12761

EPILOGUE

Since this meeting, the U.S. Department of Energy ECUT Division, the U.S. Air Force Non-Metallic Materials Division of the Materials Laboratory, the National Science Foundation, and National Bureau of Standards have agreed to jointly sponsor ACTIS. An intergovernmental agency, intersociety cooperative program on the establishment of ACTIS has begun.

The overall system planning and technical content is being addressed by three committees that represent tribology experts from government, universities, and industrial laboratories. The committee relationships are shown in Figure E-1. The system is being managed by a Government Steering Committee, chaired by Dr. S. M. Hsu of the National Bureau of Standards. This committee is composed of individuals who are currently managing government-sponsored tribology programs and whose organizations have contributed the seed funds for the initial stages of this program. This Government Steering Committee is advised by a Technical Advisory Committee chaired by Professor E. E. Klaus and an Industrial Liaison Committee chaired by Dr. C. Rowe. The Technical Advisory Committee is composed of internationally recognized tribologists who will evaluate the technical content of the program, review the data and advise on data validity, coordinate technical activities with the Technical Societies and Industrial Liaison Committee, and recommend technical areas for support. The Industrial Liaison Committee will coordinate the solicitation of industrial support in terms of manpower and data, and participate in recommending project direction. The system activities will be coordinated by a technical liaison.

The system is being implemented in three phases as shown in Figure E-2. In Phase I, principally under government sponsorship, a prototype system is being developed. This system is PC-based, such as an IBM PC or other compatible workstation. The prototype system will contain the Numeric, Design, and Newsletter databases. In Phases II and III, the Bibliographic, Research-in-Progress, and Product and Services Directory databases will be added to the prototype system, which will form a building block for a more comprehensive system. Funding for these latter two phases will be generated from the sale and distribution of the prototype system PC-disks and solicitation of moneys from industrial sources. When these moneys reach a certain preset level, a Joint Committee on Tribology Information Systems, Inc. will be established and these moneys will be distributed by this committee. This committee will be self-supported and, as government funding decreases, this committee will be the sole manager of the program.

The Prototype System

The prototype system will form the building block on which the comprehensive system will be built and will contain the Numeric, Design, and Newsletter databases as shown in Figure E-3. The Numeric Database will contain 10 subject areas that were recommended by the Technical Advisory Committee. These data include properties data, and tribo, component, and system data. The Technical Advisory Committee has also recommended 20 internationally recognized experts--two for each area--who have agreed to contribute their time and effort to this program. These experts will survey their respective fields, evaluate the pertinent tribological data, and provide 'best value'

data for inclusion into the database. These 'best values' will be in standardized units and of a form usable in the design database.

The Design Database will contain design calculations and design codes. An ASME/Joint Societies Design Task Force is in the process of evaluating these codes and has recommended that six design calculations and four design codes be included in the Design Database. The design calculations have been contributed by code designers while the design codes have been solicited under a request-for-proposal. The codes in this database must be standardized, and the codes are being modified so that common interactive screens are used. In addition, the default parameters such as geometric characteristics and numerical data input are being incorporated. The developers of these codes are working closely with the system architecture engineers to accomplish this task.

A Computerized Tribology Information System

PROGRAMMATIC ORGANIZATION

Government Steering Committee

S. M. Hsu, Chairman
T. Levinson
S. Jahanmir
B. McConnell

Technical Advisory Committee

E. Klaus, Chairman
D. Dowson
H. Czichos
H. Cheng
F. Ling
M. Peterson

Industrial Liaison Committee

C. Rowe, Chairman
D. Hays
A. Hughes
D. Flom
V. Vedeven

Technical Liaison

S. Danyluk

System Architecture

LANL

Numeric Database

Internationally recognized experts contribute data

ASME/Joint Society Design Database Task Force

6 Codes

Figure E-1 The Flow Chart Showing the Programmatic Organization of A Computerized Tribology Information System

Phase I (government-sponsored)

* Prototype System (PC-based)
  Numeric Design Newsletter

Phase II (government-sponsored;
industry support; sale of
PC discs)

Establish Joint Committee on
Tribology Information Systems, Inc.

* Prototype System
  Numeric Design Newsletter
  RJP, Bibliog., Pdt L

* Comprehensive System

Phase III (Joint Committee on Tribology
Information Systems, Inc.)
self-supported

* Comprehensive System

Figure E-2 Schematic of the Implementation of Phases I, II, and III

Phase I

PROTOTYPE SYSTEM

Numeric Database

(Recommendations of Technical Advisory Committee)

Properties Data
- Metals and Ceramics
- Lubricants and Additives

Tribo Data
- Lubricated Friction and Wear
- Abrasive Wear
- Erosive Wear
- Metal Cutting and Machining

Component Data
- Rolling Element Bearing
- Gears

System Data
- Reciprocating Engines
- Transmissions

Design Database

(Recommendations of ASME Design Task Force Committee)

Design Calculations
- Contact stress analysis
- Wear prediction
- Bearing failure diagnosis
- Bearing/shaft load

Design Codes
- Hydromatic journal bearings
- Ball bearings
- Spur gears
- Face seals
- Hydrodynamic thrust bearings
- Roller bearings
- Bearing-type selection guide

Figure E-3 Contents of the Prototype System Being Developed in Phase I

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J. Rumble and L. Sibley

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

A workshop was held in July 1985 to address the needs for a computerized tribology information and data system, as well as possible implementation schemes. The meeting was sponsored by the American Society of Mechanical Engineers, Research Committee on Tribology, the Department of Energy, Energy Conservation and Utilization Technology Division, and the National Bureau of Standards. The views of a broad sector of industry, academia, and government were obtained over a four-week period through participation by about 60 individuals. Specific categories that were treated were design, numeric data, bibliography, research in progress, newsletter, and product directory. The principal discussion content and the recommendations in each subject category are summarized here. There was general agreement that a system of this type would be broadly useful to the engineering community for the purpose of design and materials selection, and for the research community as an important aid in information access and flow. The workshop recommendations detailed four phases of development, starting with a demonstration prototype system and concluding with a full-scale operating data and information base. Specific plans in each phase and for each subject area were developed and are presented here. While continual input will be sought from the technical community to refine those plans, it is hoped that immediate efforts can begin in at least some of the areas, and that system use will quickly develop to a significant level, both nationally and internationally.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

computer data systems; computerized data; databases; friction; information systems; materials; materials data; tribology; wear

13. AVAILABILITY

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